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THE DANISH "DANA"-EXPEDITIONS 1920—22
IN THE NORTH ATLANTIC AND THE GULF OF PANAMA

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OCEANOGRAPHICAL REPORTS EDITED BY THE "DANA"-COMMITTEE

No. 3

CONTRIBUTION TO THE HYDROGRAPHY OF THE NORTH ATLANTIC

THE "DANA" EXPEDITION 1921—22.

BY

J. P. JACOBSEN

WITH 25 TABLES AND 63 FIGURES IN THE TEXT

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1. INTRODUCTION

The present paper will deal with the hydrographical material collected in the Atlantic in 1921—22 during the "Dana" Expedition under the direction of Prof. Johs. Schmidt. The plan and preparations for the hydrographical work were drawn up by the director of the expedition in conjunction with the hydrographer Dr. J. N. Nielsen, who accompanied the first part of the expedition until the "Dana" left Gibraltar.

The director of the expedition has in all cases settled the position of the hydrographical stations and the depths at which observations were taken. After Dr. J. N. Nielsen was landed at Gibraltar, the physicist Cand. mag. Johs. Olsen and the ship's doctor, N. C. Andersen, assumed the role of observers. At the end of the expedition the tables published by Johs. Schmidt in the report No. 1, part III of the Oceanographical Reports from the Danish "Dana"-Expeditions 1920—22 were drawn up by Johs. Olsen. They include the whole of the hydrographical material collected by the "Dana" and in this form were handed over to me by Prof. Johs. Schmidt for further elaboration.

The material collected consists of temperature, salinity and oxygen determinations from several stations marked 1100—1387. The position of the stations can be seen from the Chart Fig. 63, where also stations from other expeditions which have been dealt with have been noted.

Apart from a few localities, especially a region in the Western Mediterranean and another in the Pacific off the Panama Canal, the stations are mainly grouped along the sections I—VI and VIII—XI, as marked on the Chart Fig. 1. The positions of these sections are noted below along with that of section VII, likewise noted on the Chart, but which has been taken from a section constructed by Georg Wüst from the American observations of H. B. Bigelow (1917).

Section I: From the West Indies (Haiti) to the Bay of Biscay.
Section II: In the Atlantic along the West Indian Islands.
Section III: In the Caribbean Sea along the West Indian Islands.
Section IV: Yucatan to Cuba.
Section V: Florida Reef to Cuba.
Section VI: Florida to the Bahamas Bank.
Section VII: Jupiter Inlet (Florida) towards the Sargasso Sea.
Section VIII: San Salvador towards the Sargasso Sea.
Section IX: Cape Norfolk towards the Sargasso Sea (western part: section IX a).
Section X: Cape Verde Islands to the Straits of Gibraltar.
Section XI: Cayenne to the Cape Verde Islands.

Even a preliminary survey of the observations gives the impression that they have been carried out with all the accuracy that modern technical methods in marine exploration ensure, nor during the further examination has there appeared any reason to suspect the presence of any grave errors either from a failure in the working of the instruments or from any other causes.

Regarding the instruments used on the expedition reference may be made to a publication of Prof. Martin Knudsen (1923). A difficulty is mentioned however in that publication with respect to the

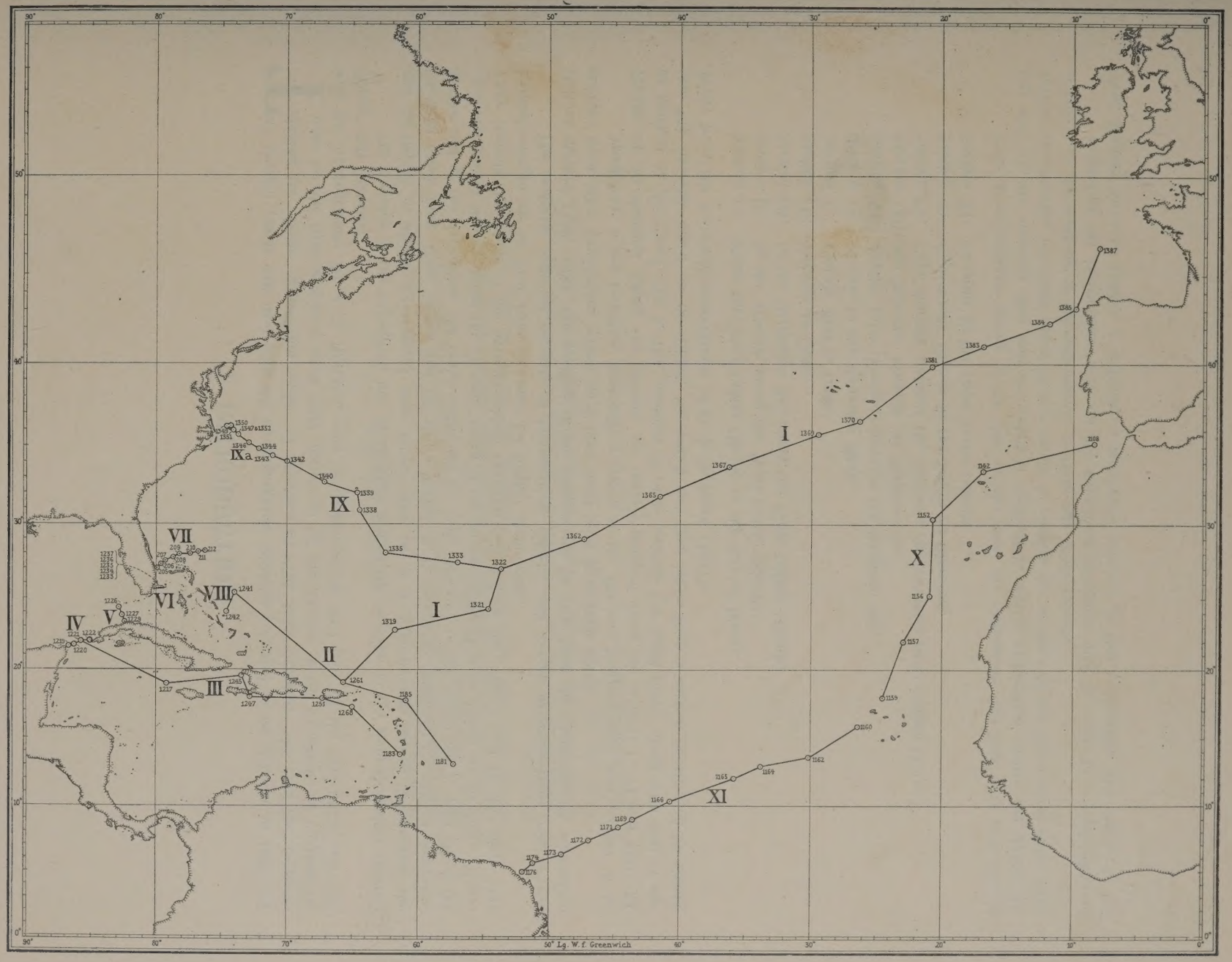

Fig. 1. Chart of the sections I—VI and VIII—XI through stations from the "Dana"-Expedition and section VII constructed by G. Wüst.

oxygen determinations, in that the metal parts of the water-bottle absorbed some of the oxygen contained in the sea water on being hauled up. The difficulty was overcome by covering the inner parts of the bottle with shellac.

A part of the material collected during the expedition has been used by Dr. J. N. NIELSEN for an investigation of the Gulf Stream (1925). He mentions there the principal forms or types of the water movements in the Atlantic, viz. the intermediate outflow from the Mediterranean, the intermediate layer with low salinity (34.6 ‰) which comes from the southern part of the Atlantic, the Equatorial Current and the hydrographical conditions in the Caribbean Sea. The Gulf Stream is specially dealt with and the author proposes to call it the Florida Current. Regarding this current he states, that it courses "along the east coast of the United States outside the coast shoal with a velocity probably varying considerably, like the breadth of the current itself, with the season. A value frequently found for the breadth is 60 miles, and the rate of speed may amount to over three miles an hour". Regarding the water carried along by the Gulf Stream it is stated to be mixed south of Newfoundland with the Labrador Current and the mixture fills the considerable area south of Iceland. The warm and salt water, which washes the coasts of Northwest Europe, J. N. NIELSEN considers to be mainly derived from the Antilles Current. These views may be regarded as on the whole undoubtedly correct, yet it may be remarked that even if the Florida Current and the Antilles Current are originally distinct, it is scarcely possible during their further course to distinguish between them in full extent.

In the following treatment of the material collected by the expedition, partly in conjunction with material from elsewhere, the object is to give a picture of the characteristic qualities and movements of the different kinds of water in the Atlantic between the equator and 50°—60° N. Lat. The accomplishment of this task must necessarily remain incomplete in essential points owing to the incomplete nature of the material available from parts of the region mentioned. On the other hand the hydrographical material collected by the "Dana"-Expedition undoubtedly can be used for the solution of some special questions not considered here. It may be mentioned in this connection, that JOHS. SCHMIDT has dealt with the hydrography of the Straits of Gibraltar (1922) and given an account of the quantities of oxygen in the water on both sides of Panama (1925).

In the preparation of the present volume I have had the assistance of the hydrographer HELGE THOMSEN during the whole work especially for the dynamical calculations and the drawing of the sections. I have also had further temporary assistance for the calculations and drawing work.

Lastly, I have received pecuniary support from the Carlsberg Fund and from the divisions of "Kommissionen for Havundersøgelser" directed by Prof. JOHS. SCHMIDT and Prof. MARTIN KNUDSEN, and have thus obtained working conditions which have made it possible for me to carry through the work. For the assistance rendered I wish to express my best thanks to all concerned.

2. THE HYDROGRAPHICAL CONDITIONS IN THE REGION INVESTIGATED BY THE "DANA" EXPEDITION

The sections marked I—XI on the Chart fig. 1 are reproduced in figures 2—11 and 13—14.

SECTION I. — FROM THE WEST INDIES (HAITI) TO THE BAY OF BISCAY.

Here we find very uniform hydrographical conditions in deep water. The 3° isotherm, for example, is present everywhere at a depth of ca. 3000 m. and the salinity is almost the same everywhere at this depth, varying between 34.92 and 34.97 ‰. Below this depth the temperature decreases to 2.56° in the deep water of the northeastern part of the section and a little less (2.44°) in 4000 m. in the southwestern

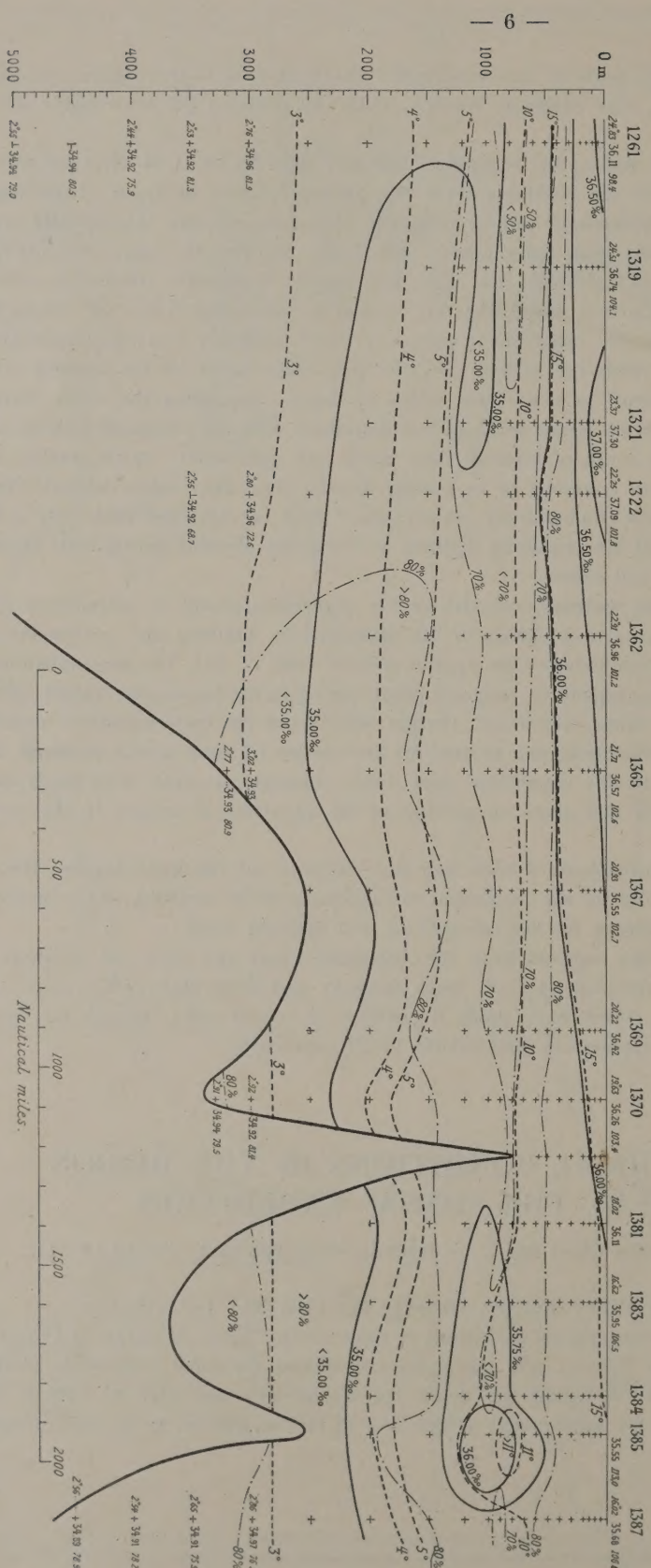

Fig. 2. Section I. — From the West Indies (Haiti) to the Bay of Biscay.

part of the section. The average salinity at a depth of 4000 to 5000 m. works out at 34.92 ‰. The oxygen content at 3000 m. is ca. 80 %, slightly diminishing towards deeper water.

In these immense water-masses in the depth we have a current coming from the north whose rate of flow is not great compared with the rapidity of surface currents in general, but which nevertheless is sufficiently great to renew the water fairly rapidly, as is shown by the large oxygen content. The main part of the water comes from the northern arctic regions, where it has sunk down from the surface on cooling. According to FRIDTJOF NANSEN (1912) the bottom-water of the Atlantic may be considered to come from the descent of surface-water south-east of Greenland. NANSEN has reckoned the temperature of this bottom-water and its salinity at 2.4 ° and 34.9 ‰, but it has to be remembered, as NANSEN notes, that the temperature of the water has increased by sinking down, owing to the change of pressure. An adiabatic descent of water of 34.9 ‰ salinity and 2 ° temperature from the surface to 5000 metres depth would have its temperature raised by 0.5 °. The increase of temperature 0.11 ° from 4000 to 5000 metres at Stat. 1261 in the southwestern part of the section off Portorico is probably due to this circumstance.

At a depth of 3000 m. and upwards to 1500—2000 m. the temperature of the water goes up to ca. 4 ° and the salinity to ca. 35.00 ‰. We have here to do with a water-layer of essentially the same nature as that below 3000 m. From the bottom and right up to a depth of 1500 to 2000 m. it still holds good that the water comes from northern regions, where it has sunk down from

the surface, but whereas the water in the deepest layers can be considered mainly to have come from a single region, the upper-most of the water masses mentioned have come from a dilution of the same kind of water as is found in the deepest layers with water from elsewhere. As will be noted later, the last mentioned water may be assumed to come from the Gulf Stream.

It is worth remarking that in a depth of about 2000 m. we find a maximum of oxygen content and that the water occurring there of ca. 4° temperature and salinity of ca. 35 ‰ is evidently more quickly renewed than the layers above and below.

Above 1500 to 2000 m. the temperature and salinity at most places of the Section increase rapidly with decreasing depth, yet in the northeastern and southwestern parts of the Section we find deviations from these normal increases. These divergences, so far as the northeastern part is concerned, are due to outflowing water from the Mediterannean at about 1000 m. which becomes mixed with the surrounding water and is recognisable among other characteristics by the temperature and salinity maximum at a depth of ca. 1000 m. at Stat. 1385. This outflow from the Mediterranean has been noted earlier by J. N. Nielsen (1912).

In the southwestern part of the Section at a depth of about ca. 1000 m. there is a salinity minimum which however is only distinct at Stat. 1261. It comes from water of low salinity, which according to W. Brennecke (1921) is formed in the Antartic region and sinks down at ca. 50° S. Lat. to ca. 1000 m. depth, mixing with the layers above and below and tending towards the north until it is taken up by other masses of water and shares in their movements. The characteristic salinity minimum of the southern water is just about to disappear at the latitudes where the southwestern part of the Section is situated. Both the Mediterranean water in the northeastern part of the Section and the intermediate water from the south in the southwestern part of the Section are bearers of an oxygen minimum which shows in the Section with values of ca. 70 % and ca. 50 %.

Between the water at a depth of 1500 to 2000 m. which as before mentioned is a mixture of Arctic water from the Greenland region and Gulf Stream water, and the intermediate waterlayer from the south at a depth of ca. 1000 m., a further mixture has arisen in the central and southwestern part of the Section. In a similar manner the water flowing from the Mediterranean mixes with the water in the depths in the northeastern part of the Section, but on account of the high salinity of the Mediterranean water its influence can be noticed down to considerably greater depths.

In the southwestern part of the Section at Stat. 1321 and 1322 water of high salinity (over 37 ‰) occurs in the uppermost layer down to a depth of ca. 100 m. This water has its origin in a central region at 20°—30° N. Lat., in the western part of which the Stations mentioned were taken. Through the anticyclonic movement on the borders of the Sargasso Sea and especially at the West Indies the surface water of high salinity forms a mixture in depths of about 1000 m. with the low salinity water coming from the south. This water-mixture is characteristic of the Sargasso Sea and adjacent areas, between approximately 100 and 1000 m. depth and is recognizable in the central and southwestern part of the Section, from the great variation of temperature and salinity with the depth. The remarkable parallelism between isotherms and isohalines at these depths in the central and southwestern part of the Section is a result of the water being an intermixture of two relatively homogeneous water masses viz. surface water of temperature ca. 22° and salinity ca. 37 ‰ and intermediate water of temperature ca. 5° and salinity ca. 34.5 ‰.

In the northeastern part of the Section, off the southwestern coast of Europe, the variation of temperature and especially salinity with the depth is relatively small at depths down to 500 m. We have here a water-mixture which has arisen on the northern boundary of the above-mentioned central region with high salinity, where the movement of the water is eastgoing.

From this region off the coast of South Europe we have several hydrographical reports: Ed. le Danois (1924), Helland-Hansen & Nansen (1926), Donald J. Matthews (1911) etc.

SECTION II. — IN THE ATLANTIC ALONG THE WEST INDIAN ISLANDS

This Section has Stat. 1261 in common with the previous Section. We see that the water in depths greater than about 1500 m. is of the same constitution as at the corresponding depths in Section I. In the greatest depths (3000 m. and more) there is nearly unmixed Atlantic bottom-water, but it has to be noticed that the oxygen of this bottom-water is generally at its lowest in the southeastern part of the Section. The southgoing movement of the bottom-water is apparently strongest along the American coast.

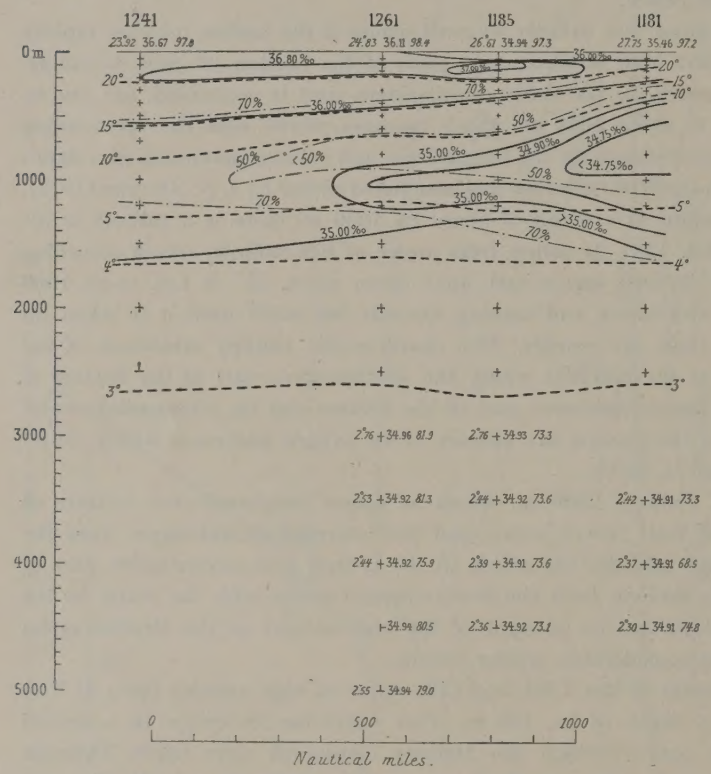

Fig. 3. Section II. — In the Atlantic along the West Indian Islands.

In depths from the surface down to ca. 1500 m., on the other hand, the hydrographical conditions are substantially different from those found in Section I and also different in the different parts of this Section.

In the southeastern part of the Section at Stat. 1181 and 1185 we find water of relatively low salinity, between 34.94 and 35.96 ‰, and high temperature, between 26.61 ° and 27.92 °, down to a depth of 50 m. This water-mixture comes partly from the northern equatorial current, partly from the central warm and salt water at the surface between 20°—30 ° N. Lat. mentioned under Section I.

In the central and northwestern part of the Section we notice an intermediate water layer of greater salinity than 36.8 ‰ at a depth of ca. 100—200 m. This water layer has its origin from the above mentioned warm and salt water at the surface in 20 °—30 ° N. Lat.

In the southeastern part of the Section we find at a depth of 800—1000 m. the already mentioned intermediate water layer with low salinity, low temperature and but little oxygen which comes from the south. This intermediate water layer is on the whole stationary in the region where the Section was taken, but it aids, together with the water of the equatorial current and the intermediate salt water at ca. 100 to 200 m. depth, in the formation of a water mixture which under the name of Antilles current moves along the row of West Indian Islands. It is comprehensible that the depth conditions along these islands favour the mixing, and we thus find in the northwestern part of the Section high and nearly uniform salinities of about 36.70 ‰ down to a depth about 300 m., although the intermediate maximum at ca. 200 m. has not yet quite disappeared.

For the continuation of the Antilles current in a northerly direction we may look to the water mixture in the uppermost 100 m., with a salinity of 36.6 ‰ and a temperature of 23.7 ° as its characteristics, still observing however that the northgoing movement carries with it some water which takes part in the rotating masses of water in the Sargasso Sea (see Chart of isobars, fig. 53).

Under the Antilles current, or belonging to it, there is between ca. 300 and 1000 m. a mixture

of the central salt water from 20 °—30 ° N. Lat. with the intermediate water of low salinity and temperature coming from the south, the last-named becoming more and more prominent at increasing depths.

SECTION III. — IN THE CARIBBEAN SEA ALONG THE WEST INDIAN ISLANDS

This Section has mainly the same direction as Section II, and both sections in several respects show the same characteristic picture of the distribution and nature of the water-layers.

An essential difference is found however in the deep water outside and inside the West Indian Islands.

Whereas outside the Islands, e. g. at Stat. 1261, the bottom temperature of the Atlantic water is ca. 2.5 ° in the greatest depths, the temperature inside the group of islands, e. g. at Stat. 1268, increases from 4.07 ° to 4.22 ° between 2000 to 4000 m. This is however the temperature on the spot, and as the adiabatic increase of temperature through the sinking down of water-masses to greater depths amounts to 0.1 ° for 1000 m., the potential temperature remains nearly the same in depths greater than 2000 m. The salinity at great depths inside the islands is also greater than in the same depths outside. The water of the deep layers in the Caribbean Sea is evidently a mixture, resulting from a flow of Atlantic water over the different thresholds between the islands.

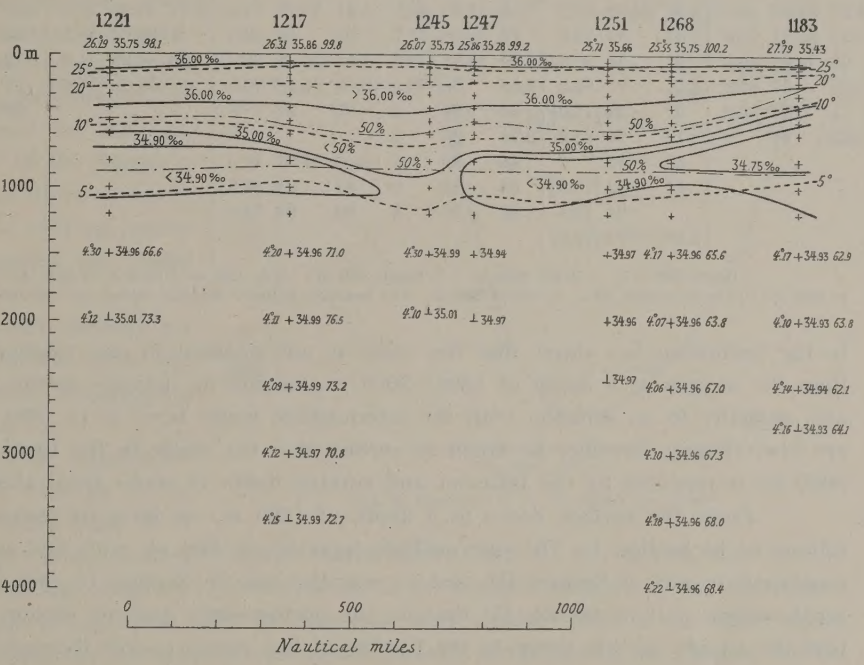

Fig. 4. Section III. — In the Caribbean Sea along the West Indian Islands.[1]

There are several of these passages between the small Antilles at a depth of ca. 1500 m., the Anegada Passage at the Virgin Islands with a depth of approximately 2000 m., Mona Passage between Porto Rico and Haiti with ca. 500 m., and Windward Passage between Haiti and Cuba with a depth of about 2000 m.

For a comparison of the characteristics of the water at a depth of more than 1000 m. outside and inside the islands some data are given on Table I.

From this Table we see, that the temperature apart from the adiabatic variation is nearly the same at all depths greater than 2000 m. inside the islands and equal to a temperature which is found outside the islands at a depth of ca. 1500 m., or a little more. Further, the salinity at depths greater than 2000 m. inside the islands is nearly the same as the salinity at ca. 1500 m. outside, yet somewhat lower, especially at Stat. 1183. This can be explained naturally from the fact, that the intermediate water-layer of low salinity at about 800 m. is most prominent to the east of the West Indian Islands, and a relatively considerable quantity of this water penetrates through the passages in the eastern part of the islands. This also explains the somewhat smaller oxygen contents at Stat. 1183 and the other Stations. Nevertheless, the relatively large oxygen contents (62—70 %) in depths greater than 2000 m.

[1] The station marked in this paper as 1268 is marked as 1269 in the tables in report No. 1 part III.

Table 1.

Depth Meter	Stations outside the islands												Stations inside the islands											
	1244			1261			1185			1181			1245			1251			1268[4])			1183[5])		
	T	S	O_2	T	S	O_2	T	S	O_2	T	S	O_2	T	S	O_2	T	S	O_2	T	S	O_2	T	S	O_2
1000	5.58	34.96	60.4	5.88	34.90	54.2	5.58	34.89	50.5	5.21	34.77	47.4	5.74	34.96	55.1	5.43	34.87	57.0	5.24	34.92	58.8	4.81	34.85	56.0
1200	4.73	35.01	70.9	4.90	99	72.3	12	35.00	61.7	04	85	53.5	74	35.01	66.5	4.46	94	64.6	4.41	92	62.4	35	91	59.2
1500	03	34.99	80.3	11	99	80.9	4.29	34.98	72.5	4.51	35.01	68.4	30	34.99	74.4	12	97	68.3	17	96	65.6	17	93	62.9
2000	3.54	97	81.9	3.43	97	82.2	3.58	95	73.0	3.61	34.98	76.5	10[2])	35.01[2])	77.6[2])	07	96	70.6	07	96	63.8	10	93	63.8
2500	31	94	80.9	07	97	[77.0]	18	94	4	05	97	8	..			08[3])	97[3])	1[3])	06	96	67.0	14	94	62.1
3000	2.95[1])	94[1])	0[1])	2.76	96	81.9	2.76	93	3		..		..			..			10	96	3	16[6])	93[6])	64.1[6])
3500		..		53	92	3	44	92	6	2.42	34.91	73.3	..			..			18	96	68.0		..	
4000		..		44	92	[75.9]	39	91	6	37	91	68.5	..			..			22	96	4		..	
4500		..		..	94	80.5	36	92	1	30	91	74.8	..			..				..			..	
5000		..		2.55	94	[79.0]		..			..		..			..				..			..	

[1]) Depth 2900 m. [2]) Depth 1950 m. [3]) Depth 2450 m. [4]) At 1800 m. T: 4.06 S: 34.96 O_2: 67.6. [5]) At 1800 m. T: 4.10 S: 34.93 O_2: 64.7 and at 2200 m. T: 4.11 S: 34.93 O_2: 63.3 [6]) Depth 2800 m. The brackets indicate that the values are uncertain.

in the Caribbean Sea show, that the water is not stagnant in any marked degree, yet it is somewhat less than the oxygen at a depth of 1500—2000 m. outside the islands, owing perhaps to some stagnation, but also partially to an infusion with the intermediate water layer at ca. 800 m., where the oxygen contents are low. It may therefore be taken as certain that the water in the Caribbean Sea at depths greater than 2000 m. is renewed by the infusion and sinking down of water from about 1500 m. outside the islands.

From the surface down to a depth of 1500 m. we have in Section III essentially the same conditions as in Section II. The intermediate layer at ca. 800 m. with low salinity is most prominent in the southeastern part of Section III, just as was the case in Section II., but is more strongly marked in the northwestern part of Section III than in the northwestern part of Section II. We may suppose therefore that the supply of this water to the Caribbean Sea comes mainly through the passages in the southeastern part of the islands.

On the other hand, the supply of the intermediate, strongly saline water at a depth of 150—200 m. comes principally through the passages in the northern part of the row of islands. In these depths we find in Section III salinities of about 37.0 ‰ in the southeastern part, and about 36.7 ‰ in the western part.

At the surface we find in Section III water which has come into the Caribbean Sea from the Equatorial Current, but owing to admixture with the underlying salt layer, the salinity of the surface increases from the southeastern to the northwestern part of Section III.

Between the water layers mentioned we find various mixtures which we shall refer to later.

SECTIONS IV—VIII. — IN WEST INDIAN WATERS

Section IV. — Yucatan to Cuba ..... greatest depth ab. 2100 m.
Section V. — Florida Reef to Cuba ..... » » » 1600 »
Section VI. — Florida to the Bahamas Bank ..... » » » 800 »
*) Section VII. — Jupiter Inlet (Florida) towards the Sargasso Sea » » » 1200 »
Section VIII. — San Salvador towards the Sargasso Sea ..... » » » 5000 »

All these sections (fig. 5—9) lie in passages which are swept by the water masses of the Florida and Antilles currents. From these waters we have many earlier investigations, among which special refe-

*) Reproduced from Georg Wüst: "Florida und Antillenstrom". Veröffentlichungen des Institutes für Meereskunde. Neue Folge A Geogr.-naturw. Reihe, Heft 12, 1924, Berlin.

rence may be made to H. B. Bigelow (1917) and Wüst (1924) as well as the previously mentioned work (page 5) of J. N. Nielsen (1925), based on the "Dana"s observations.

With exception of section VIII the depths at these sections are relatively shallow. As mentioned before, the sections already dealt with show that the movements of the surface water both outside and inside the West Indian Islands tend to the west, forming a continuation of the Equatorial Current, and that the salt and warm water from the surface of the Sargasso Sea has a south-going tendency down towards the West Indian Islands, there sinking below the surface stream and following the latter towards the west.

In all the above-mentioned sections we find this intermediate, salt water-layer from the Sargasso Sea at depths about 200 m. recognizable from salinities greater than 36.5 ‰.

In sections IV and V this water-layer is somewhat equally distributed over the whole breadth of the sections. On the other hand, it is only prominent at the eastern part of the section Florida-Bahamas Bank, and in the section discussed by Wüst, from Jupiter Inlet towards the Sargasso Sea, it appears as an isolated nucleus in the western part and as a tongue of water which is connected with the Sargasso Sea's surface water in the eastern part.

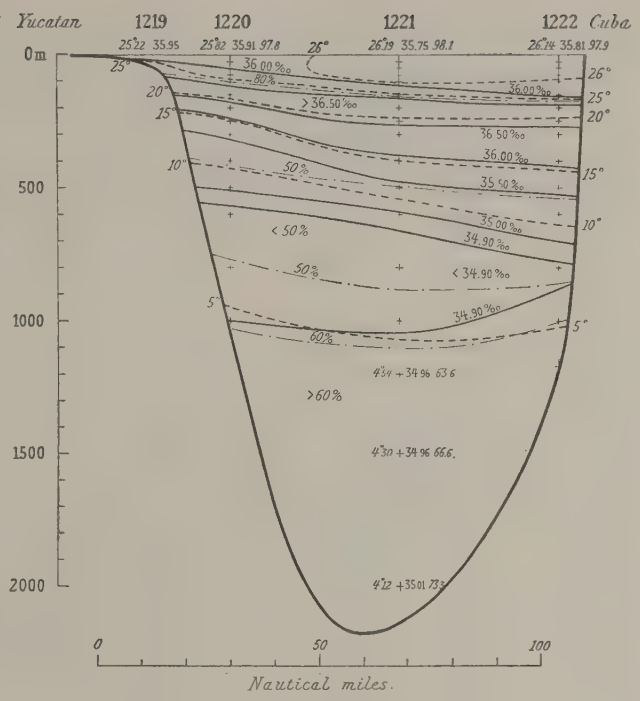

Fig. 5. Section IV. — Yucatan to Cuba.

In the detailled treatment given by Wüst of the hydrodynamic conditions in the Florida and the

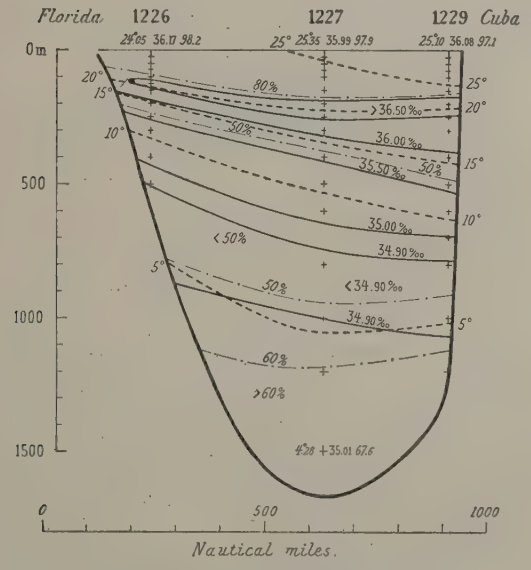

Fig. 6. Section V. — Florida Reef to Cuba.

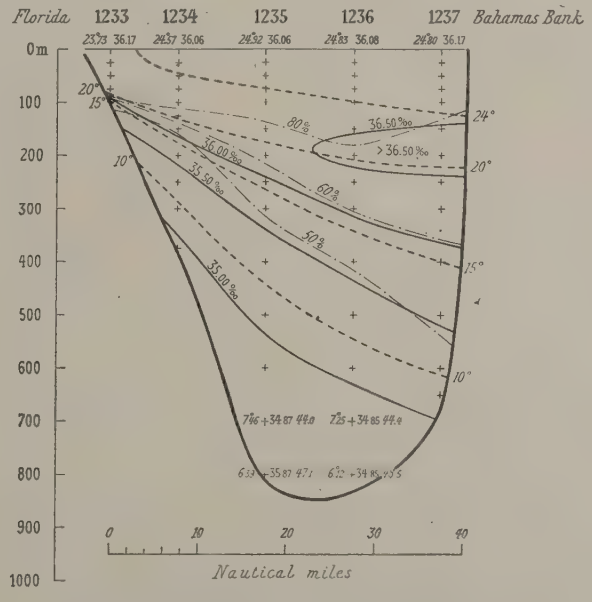

Fig. 7. Section VI. — Florida to the Bahamas Bank.

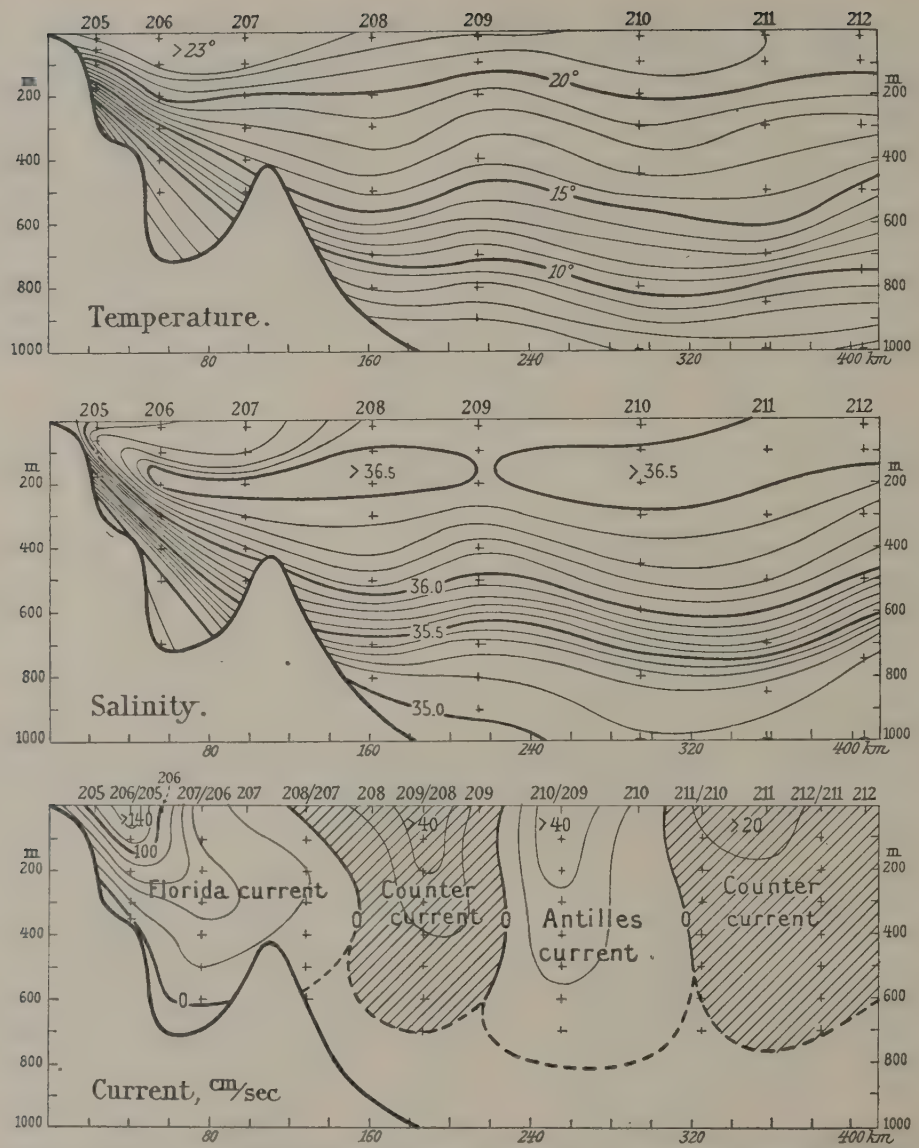

Fig. 8. Section VII. — Jupiter Inlet (Florida) towards the Sargasso Sea reproduced from Georg Wüst (1924).

Antilles Currents it is shown, how this distribution of the salinity is connected with these currents and at the same time with the opposing currents at their boundaries.

A clear picture of the currents in the different parts of the section is given in the figure (Fig. 8), reproduced from Wüst.

As emphasized by Nielsen and Wüst, the steep inclination of the isotherms and isohalines is an indication of the strong currents which appear in these sections.

By way of summarising the hydrographic conditions in the region of these sections, Table 2 (p. 14) shows for the "Dana" stations 1220—1244:

1) temperature and salinity at the surface,
2) depth, temperature, salinity and oxygen contents for the salt water-layer which occurs at ca. 100—200 m. depth, the corresponding values being chosen for the depth in which the highest salinity was observed.
3) The depth, temperature, salinity and the oxygen contents for the water-layer of low salinity, usually occurring at 800—1000 m. depth, whereby the corresponding values are chosen for the depth in which the lowest salinity was observed. With regard to the last values it should be mentioned, that observations from the greatest depth recorded are noted at several places, as shown in the Table.

Finally, it has to be remarked that Stat. 1219 and Stat. 1233 are not included in the series given, owing to their shallow depths, 35 and 100 m. respectively.

Following the position of the Stations from Stat. 1220 to Stat. 1237 on the Chart, fig. 63, we can see that the salinity at the surface increases from about 35.8 ‰ to ca. 36.1 ‰ from the section Yucatan—Cuba to the section Florida—Bimini, and that the maximum salinity on the same tract diminishes from ca. 36.7 ‰ to ca. 36.6 ‰. The increase of the surface salinity whilst the water moves over the tract, is possibly a consequence of intermixture with the salt-layer below. On the other hand, the diminishing salinity of the salt-layer is only in part due to an intermixture with the upper layer, as it is probably due in greater part to infusion with the under-lying water-mixture, which contains water from the intermediate layer of low salinity at a depth of ca. 800 m. That we conclude the intermediate layer of ca. 200 m. depth is mainly mixed with the underlying water, is based on the fact, that for the salinity in the layer with maximum salinity we find an agreement between the temperature, salinity and oxygen contents, in such a way that a low temperature accompanies a low salinity and small quantities of oxygen. Consideration of the variation in the specific gravity with the depth also permits us to suppose that the layer with maximum salinity more easily mixes with the underlying than with the overlying water.

The water-layer of minimum salinity at a depth of ca. 800 m. does not greatly change its salinity and temperature over the tract discussed, nor do the oxygen contents of this layer show great changes. It should be mentioned, that the depth for the oxygen minimum is usually somewhat less than the depth for the minimum salinity.

At the stations 1220—1237 we have obviously to do with the same water-masses, since these move in the Caribbean Sea through the eastern part of the Gulf of Mexico, and through the Florida Straits. On the other hand, at the Stations 1238 and 1239 in Providence Channel north of the Florida-Bimini section the water is obviously of a different kind. This comes partly from the previously mentioned Florida Current, partly from the Antilles Current outside the row of islands. We can see that this is the case from a consideration of the two stations 1241 and 1242, in the Antilles region, (see Table 2). At these Stations the surface

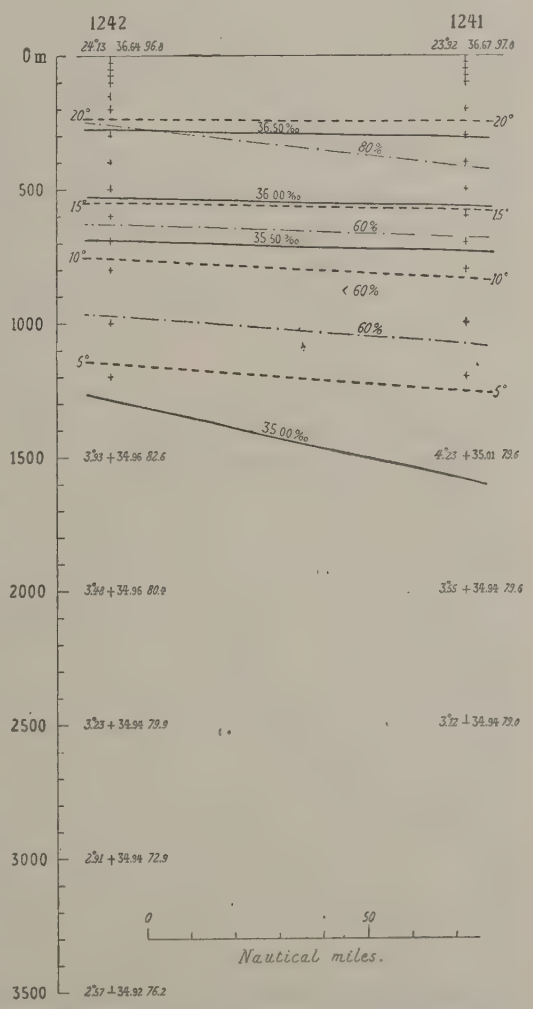

Fig. 9. Section VIII. — San Salvador towards the Sargasso Sea.

Table 2.

Station	Surface		Maximum of salinity				Minimum of salinity			
	Temp.	Sal.	Depth	Temp.	Sal.	Oxyg.	Depth	Temp.	Sal.	Oxyg.
1220	25.82	35.91	150	22.22	36.65	72.1	800	5.63	34.81	51.9
1221	26.19	75	200	21.96	73	71.5	800	6.66	83	45.7
1222	14	81	200	66	69	70.3	800	7.43	88	44.1
1224	25.78	90	200	20.96	69	68.7	800 1000	6.80 5.84	85 85	44.1 49.1
1225	24.81	36.15	200	19.36	44	60.2	800	70	87	50.7
1226	05	17	125	20.41	53	65.4	500[1]	7.76	90	43.9
1227	25.35	35.99	200	76	56	65.6	800	6.30	81	42.8
1228	41	36.15	200	99	69	68.7	800	33	85	44.8
1229	10	08	200	21.88	69	70.6	800	92	87	44.5
1231	39	17	200	98	69	71.1	800[1]	18	87	48.0
1232	24.78	18	200	22.40	71	71.6	588[1]	11.26	35.39	48.6
1234	57	06	125	20.7	49	69.1	375[1]	8.05	34.94	43.5
1235	92	06	150	21.27	42	74.7	700 800[1]	7.46 6.39	87 87	44.0 47.1
1236	83	08	200	20.26	60	65.8	700 800[1]	7.25 6.12	85 85	44.4 48.5
1237	80	17	150 200	23.61 20.86	62 62	71.7 66.7	650[1]	8.90	35.03	42.7
1238	23.50	45	200	21.20	67	81.8	600[1]	11.80	48	56.6
1239	42	51	200	20.76	71	79.9	Measurements to 2500 Metres. No Minimum			
1241	92	67	200	21.43	80	86.5	..	..	..	..
1242	24.13	64	150 200	22.43 21.36	78 78	86.9 82.0	..	..	..	..
1243	25.55	35.84	150	23.09	83	86.8	..	..	..	..
1244	01	36.13	200	21.38	92	80.2	1000	5.58	34.96	60.4

[1]) The greatest depth in which measurements have been taken.

salinity is ca. 36.65 ‰ or about 0.5 ‰ higher, and the temperature of the surface nearly 1° lower than in the Florida Straits. The maximum salinity which, as at the stations earlier referred to in Table 2, lies at ca. 200 m. depth, amounts to 36.80 ‰, and is thus considerably higher than that in the Florida Straits. The oxygen contents in the layer with maximum salinity are about 80 % and thus much higher than the oxygen in the corresponding layer in the Florida Straits.

Both at stations 1241 and 1242 and at the stations 1220—1237, previously described, the intermediate layer at ca. 200 m. comes from the central surface-layer with high salinity found at ca. 25° N. Lat. but whilst the water-layer which has passed the Caribbean Sea and the eastern part of the Gulf of Mexico has had its salinity as well as its oxygen diminished by mixture, especially through the under-lying layer, the corresponding water-layer at the stations 1241 and 1242 is connected more directly with the central surface layer and has also not been influenced in such a high degree by the Equatorial Current.

Under the layer of maximum salinity we find at stat. 1241 and 1242 essentially the same water-mixture as at the stations mentioned earlier, but it has to be noticed that the salinity minimum at a depth of ca. 800 m. has disappeared, whilst the oxygen minimum of about 50 % is found at a depth of 800—1000 m., thus with some greater oxygen contents than at the earlier mentioned stations.

In Table 2 the stations 1243 and 1244 off Windward Passage between Cuba and Haïti, outside the islands, are also included. At these stations we have a lower surface salinity than at stations 1241 and 1242, and this is due to the Equatorial Current. On the other hand, the maximum salinity at a depth of about 200 m. is greater at stat. 1243 and 1244, than at stat. 1241 and 1242, and it may therefore be assumed, that the water with this high salinity is carried more directly there than to the stat. 1241 and

1242. This may be due partly to the water coming from the north at stat. 1243 and 1244 finding a way of escape into the Caribbean Sea between the islands, but at stat. 1241 and 1242 we have likewise probably an infusion of water from the local rotation in the Sargasso Sea (v. isobar Chart, fig. 53).

We can form some idea of further movements of the Florida and the Antilles Currents with the assistance of the section, fig. 8, reproduced from Wüst. This is based on the American observations of 1914, which are also dealt with by Bigelow (1917).

According to these observations the maximum salinity at 200 m. has been practically the same in the Florida Current (st. 207) and the Antilles Current (st. 210), namely 36.56 ‰ and 36.55 ‰ resp., but

Table 3.

Stations	195		193		191		189		187		185		183		181		179	
Depth m.	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S
0	21.70	36.49	21.75	36.53	21.42	36.56	19.66	36.47	19.30	36.51	19.80	36.42	21.00	36.62	19.37	36.42	18.64	36.40
20	70	..	73	..	36	..	63	..	23	..	89	..	19.97	..	19.28	..	40	44
100	38	36.51	19.88	36.53	18.20	36.60	20.83	36.45	26	36.49	55	36.49	20.89	36.62	18.78	36.42	50	44
200	..	..	..	..	..	..	..	..	..	..	..	..	19.22	53	89	44	52	42
300	17.90	36.47	18.01	36.53	17.70	36.33	17.95	36.45	..	36.47	17.30	36.35	..	..	..	..	..	..
400	..	..	..	..	..	..	..	..	..	..	..	..	17.41	..	17.13	36.33	17.15	36.31
600	14.07	35.82	14.67	35.93	15.11	35.95	16.18	36.13	16.44	36.24	17.40	35.79	16.31	36.17	15.20	35.93	14.52	35.90
800	9.87	21	..	19	11.11	35	..	35.55	13.05	35.70	9.67	21	13.68	35.73	..	37	13.74	77
1000	..	03	(10.05)	(03)	..	03	8.37	08	9.05	19	..	10	7.67	..	7.38	07	9.65	37
1200	..	01	5.35	05	5.53	07	..	34.99	..	05	..	..	..	..	..	03	..	..
1400	4.37	34.97	4.54	..	4.70	..	5.00	99	5.08	34.99	4.44	..	5.52	..	4.88	..	..	..
1800	3.74	99	3.74	35.01	3.79	34.96	4.10	97	4.01	99	3.77	35.01	4.39	..	3.89	35.01	4.40	34.99

there is a great difference in the surface salinity, which for stat. 207 is 36.17 ‰ and 36.42 ‰ for stat. 210. Further, at the Stat. 211 and 212, lying more to the east, the salinity at a depth of 200 m. was ca. 36.5 ‰, but reaches here just a high and even higher values on the surface.

For the elucidation of the hydrographic conditions to the east of the section referred to, we may give here (Table 3) from Bigelow the results of measurements at 9 stations on the stretch from the above section to the Bermudas. The stations are marked on the Chart fig. 63 with the numbers 195—179, noted on Table 3.

It will be seen that the salinity from the surface down to about 300 m. is nearly the same for all stations. In conformity with the water-movement to be seen from the isobar Charts, fig. 53—56, we may take it for granted that the water has originally come from the Antilles Current and possibly from the Florida Current, but that after going northward it turns again to the south. So much mixing has taken place during this movement that the water has become nearly homogeneous. In all probability the cooling of the surface in the more northern latitudes has contributed to this result. Regarding the 9 stations mentioned the salinity at 600 m. is highest at Station 187, which according to the isobar Chart, fig. 53—56, lies in the central part of the anticyclonic water-movement at depths of 200—500 m. in the western part of the Sargasso Sea.

Observations from the deeper layers are generally in good agreement with the results of the "Dana"s work in the adjacent regions. A few observations seem uncertain, especially the temperature and salinity at a depth of 1000 m. at stat. 193.

We may therefore conclude that there is but little difference between the intermediate maximum salinity in the Florida Current and that in the Antilles Current north of the little Bahamas Banks. It is for both ca. 36.5 ‰. Further, Bigelow's researches show that to the northeast of the Antilles Current, in a direction towards the Bermudas, there is a region with a uniform salinity of about 36.5 ‰ from the surface down

to 200—300 m. depth. This water, which participates in the rotating movement in the western part of the Sargasso Sea contributes to the formation of the Antilles Current along with water coming from the east. The salinity at the surface of the latter at the Little Bahamas Banks amounts to 36.4—36.5 ‰, whereas the surface salinity of the Florida Current is somewhat lower: 36.1 to 36.2 ‰.

Regarding the variation of the salinity with the season of the year, it may be noticed that the "Dana" observations at stat. 1232—37 and 1241—42 were taken about the middle of February, the observations discussed by Wüst from Stat. 205—212 from the 20th to the 23rd of March, and the Stations in Table 3 at the end of February.

With the aid of a series of measurements made by the "Dana" to the west of St. Croix at ca. 17° 43′ N. Lat. and 64° 55′ W. Long. in the period 6/3—23/4 1922 we obtain an impression of the stability

Table 4.

Month	Day	Hour	Place		Surface		Max. Salinity				Min. Salinity			
			N.L.	W.L.	Temp.	Salin.	Depth	Temp.	Salin.	Oxyg.	Depth	Temp.	Salin.	Oxyg.
III	6	10^{15} a.m.	17°43′	64°55′,5	25.22	35.73	100	23.17	36.98	90.7	800[1])	6.85	34.85	47.3
,,	13	1^{45} p.m.	17°45′	,,	25.15	35.82	100 150	23.86 21.52	36.89	92.1 85.1	800[1])	6.66	34.83	44.1
,,	,,	5^{30} p.m.	,,	,,	25.14	35.84	100	23.61	36.92	89.3	800[1])	6.60	34.83	45.2
IV	15	8^{00} a.m.	,,	,,	25.50	35.88	150	21.89	37.00	85.2	800[1])	6.85	34.85	46.5
,,	19	1^{30} p.m.	17°43′	64°55′	25.54	35.88	150	20.97	36.87	81.3				
,,	,,	7^{00} p.m.	,,	,,	25.46	35.91	150	22.20	37.00	87.5				
,,	20	1^{00} a.m.	,,	,,	25.36	35.91	150	21.30	36.92	82.2				
,,	,,	7^{00} a.m.	,,	,,	25.44	35.91	150	22.28	37.01	88.9				
,,	,,	1^{00} p.m.	,,	,,	25.53	35.90	125	22.59	37.01	91.2				
,,	21	9^{00} p.m.	,,	,,	25.45	35.93	125	22.64	35.07					
,,	22	3^{00} a.m.	,,	,,	25.53	35.97	125	22.13	35.05					
,,	,,	9^{25} a.m.	,,	,,	25.61	35.95	125	23.48	37.05					
,,	,,	3^{30} p.m.	,,	,,	25.71	35.95	125	22.65	37.03					
,,	,,	6^{30} p.m.	,,	,,	25.63	..	125	22.58	37.03					
,,	,,	9^{45} p.m.	,,	,,	25.59	..	150	20.49	37.01					
,,	23	3^{45} a.m.	,,	,,	25.52	..	125	22.38	37.01					
,,	,,	10^{30} a.m.	,,	,,	25.71	..	125	22.71	37.03					

[1]) Greatest depth in which observations were taken.

of the hydrographic conditions in that region, where water of high salinity penetrates through passages in the northeastern part of the row of islands into the Caribbean Sea as an intermediate layer. The observations noted in Table 4 have been taken from these measurements.

It will be seen, that the surface salinity has been increasing in the course of the $1^1/_2$ months over which the observations extend. The intermediate maximum salinity, which is ordinarily found at 125—150 m., has also been subject to variations but not so regularly as the surface salinity. Where determinations of the oxygen in the intermediate salt-layer are available, this appears to amount in round numbers to between 80 and 90 %. There is an indication of a relation between the salinity and the oxygen contents, in so far as a higher salinity is connected with a great amount of oxygen. This may be due to alterations in the inflow of salt water in connection with the tidal movements.

On account of the insufficient depth at the station the intermediate salinity minimum at 800 to 1000 m. (see sections II and III) does not appear, but its value is scarcely very different from that of the salinity found at 800 m. It has practically remained the same for a month. On the other hand, the temperature has changed 0.25° in the course of 2 days. The oxygen contents were about 45 % at a depth of 800 m. In reality the oxygen minimum with nearly the same value lies at a somewhat less depth.

SECTION IX. — CAPE NORFOLK TOWARDS THE SARGASSO SEA

The deepest layers of more than 2000 m. in this section (fig. 10) show the same hydrographic conditions as were found in section I. For depths less than 2000 m. the Bermudas (stat. 1339) form a characteristic boundary between the eastern part of the section, where the conditions are almost the same as at the meeting place of Sect. I and IX, (stat. 1322), and the western part where special conditions are apparent.

East from the Bermudas the intermediate salinity minimum at ca. 1000 m. depth, which was found in the southwestern part of section I, is not to be seen. Nevertheless the water which bears the minimum in more southern latitudes also makes its influence felt in sect. IX, for the water between 1000 and 1500 m. depth at Stat. 1322, 1335 and 1338 has the same salinity, 34.07 ‰, and there is an oxygen minimum of ca. 55 % at a depth of 800 to 1000 m. in the same part of the section.

At the surface the salt layer mentioned under section I, is found in nearly unmixed state with a salinity varying from 36.74 ‰ to 37.09 ‰.

Between the surface and 1000 m. depth the water is a mixture of the central salt water at ca. 25° N. Lat. and the intermediate water coming from the south at ca. 1000 m. depth, but this mixture cannot be considered to have arisen to any great extent at the places where section IX was taken but, rather at the southern borders of the region for the salt and warm water.

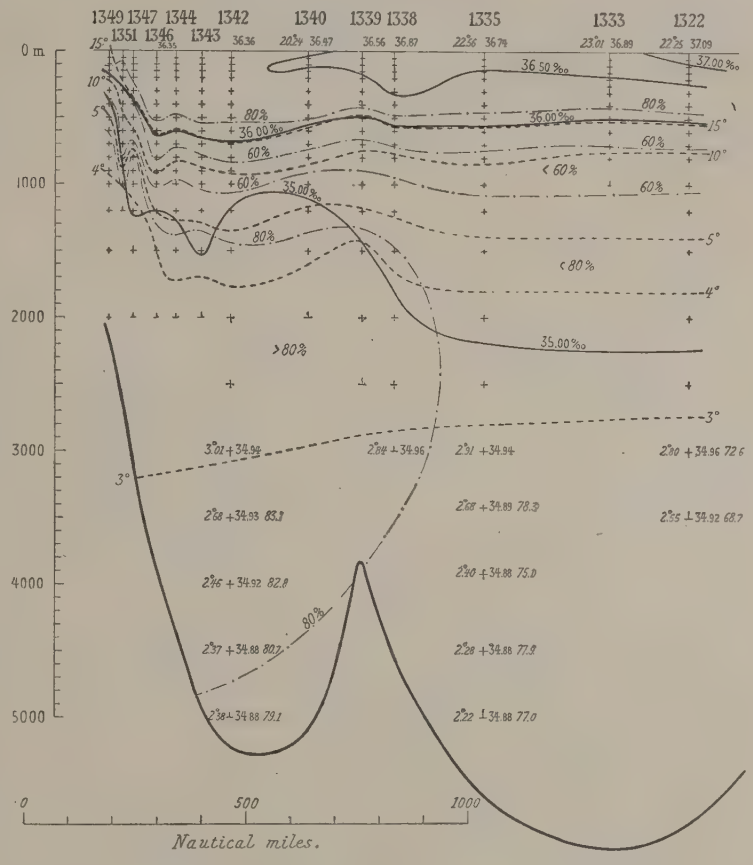

Fig. 10. Section IX. — Cape Norfolk towards the Sargasso Sea.

Between 1000 and 2000 m. we find a water mixture of the same composition as in the southwestern part of section I in the same depths.

West of the Bermudas, from these islands about as far as to Stat. 1346, which lies at a distance of ca. 120 miles from the coast, almost the same conditions as to the east of the Bermudas are still found in depths greater than ca. 300 m. The salinity of the intermediate layer at a depth of 1000 m. is somewhat less marked, but this layer is nevertheless recognizable from the small amounts of oxygen, which are similar to those found east of the Bermudas.

The surface salinity on the stretch from stat. 1346 to the Bermudas increases from 36.35 ‰ at stat. 1346 to 36.56 ‰ at stat. 1339. The salinity of the surface-water is thus considerably lower here than east of the Bermudas. This is undoubtedly due to the influence of the water which is carried up along the American coast by the Antilles and Florida Currents and then contributes in part to the formation

of the previously mentioned (page 15) anticyclonic water-movement in the western part of the Sargasso Sea to the west and southwest of Bermudas.

In depths about 100 m. below the surface along this tract west of the Bermudas we find a salinity of ca. 36.50 ‰ along with a temperature of about 19° and oxygen contents nearly 100 %. This intermediate layer may be considered to come partly from the central portion of the previously mentioned anticyclonic water-movement in the western part of the Sargasso Sea, in conformity with the measurements made by Bigelow (see Table 3 p. 15), partly from the warm and salt surface water lying more to the east. It is interesting now that the mixtures taking place, possibly conjoined with surface cooling, give rise to a comparatively homogeneous water-layer down to about 300 m. depth in the neighbourhood of the Bermudas. The depth conditions on the Bermudas plateau probably intensify the rate of mixing.

Table 5.

Station	158		159		160		161		163		166		169		171		173		175		177	
Depth m	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S
0	12.30	34.94	7.00	33.04	9.15	34.29	21.50	36.38	18.95	36.49	19.15	36.45	18.95	36.44	18.95	36.45	18.85	36.44	18.90	36.38	19.10	36.42
20	11.45	67	6.85	32.95	40	29	50	35	90	53	20	47	19.00	38	19.03	44	90	44	90	38	18.95	40
100	15	76	..	..	12.00	35.28	35	44	85	44	18.80	45	18.85	44	18.84	45	70	42	90	36	95	44
200	..	..	..	..	9.45	37	19.60	44	90	49	30	42	83	42	65	44	10	44	90	45	97	42
300	11.40	35.19	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
600	[1] 4.78	[1]) 01	..	..	..	..	15.20	35.99	15.70	36.08	15.60	36.08	15.60	36.26	16.10	36.08	16.50	36.17	16.30	36.17	15.50	36.00
1000	[2]) 20	[2]) 01	..	..	..	..	10.40	25	10.05	35.41	10.00	..	10.50	..	(6.70	35.71)	11.60	..	..	..	..	..
1800	3.55	34.94	..	..	..	..	3.70	..	3.80	34.97	4.05	..	..	35.01	4.00	34.99	3.90	34.96	4.20	..	3.60	34.99

[1]) Depth 700 m. [2]) Depth 1100 m.

The observations taken by the "Dana" along the tract mentioned refer to the middle of May 1922. For comparison Table 5 also gives some observations taken by Harry B. Bigelow (1917) between Chesapeake Bay and the Bermudas in January and February 1914. The numbers of the stations in the Table are noted on the Chart, fig. 63.

It will be seen that these measurements give the same picture of the temperature and salinity conditions as the observations of the "Dana". Yet the salinities given by Bigelow for the region near the Bermudas are lower than the "Dana"s results. Between stat. 1346 and the American coast the surface layers down to about 1000 m. display very special conditions, as can be seen from the very sloping position and partially bent course of the isotherms and isohalines. Hence it may be concluded that strong currents exist in this tract down to about 1000 m. depth, tending mainly in a northerly direction.

In section IXa (fig. 11) the part of section IX which lies west of stat. 1344 is repeated. The vertical and horizontal scales of section IX are enlarged in the proportions of 2/1, and 10/1 respectively.

We see from this section that the curves for temperature, salinity and oxygen have a parallel course in the deep layers. The deviations may be referred essentially to unavoidable errors of observation. In these layers we have a mixture of the surface water from the central region at ca. 25° N. Lat. and the intermediate water-layer coming from the south with low salinity, but it appears from the section that a water mixture with a definite composition lies in the western part of the section at a higher level than in the eastern part.

At the westernmost station of the section, stat. 1349, we find the characteristic cold and but little saline water, which forms the well-known "cold wall" along the American coast. According to Bigelow (1915, page 252) this water mainly comes from the Gulf of St. Lawrence, moving towards the south after leaving the Cabot Straits. The distance from the coast to stat. 1349 is ca. 50 miles and the cold water of low salinity must have reached somewhat farther out at the time the measurements were taken, in the

middle of May 1922. Somewhat more to the east at stat. 1351, 60—70 miles from the coast, we find the salt and warm water which has its origin from the Florida and the Antilles Current.

For comparison with the conditions found on the "Dana" Expedition a section made by Bigelow (1917, p. 48) through the Stat. 159, 160, 158 and 161, noted in Table 5, is given in Fig. 12. The positions of the stations are shown on the Chart, fig. 63. It will be seen that the isohalines outside the shelf have a nearly vertical direction and, as Bigelow remarks, we must conclude that a descent of the water takes place outside the shelf. In this way arises a mixture of the water of the Florida and Antilles Current with the underlying water.

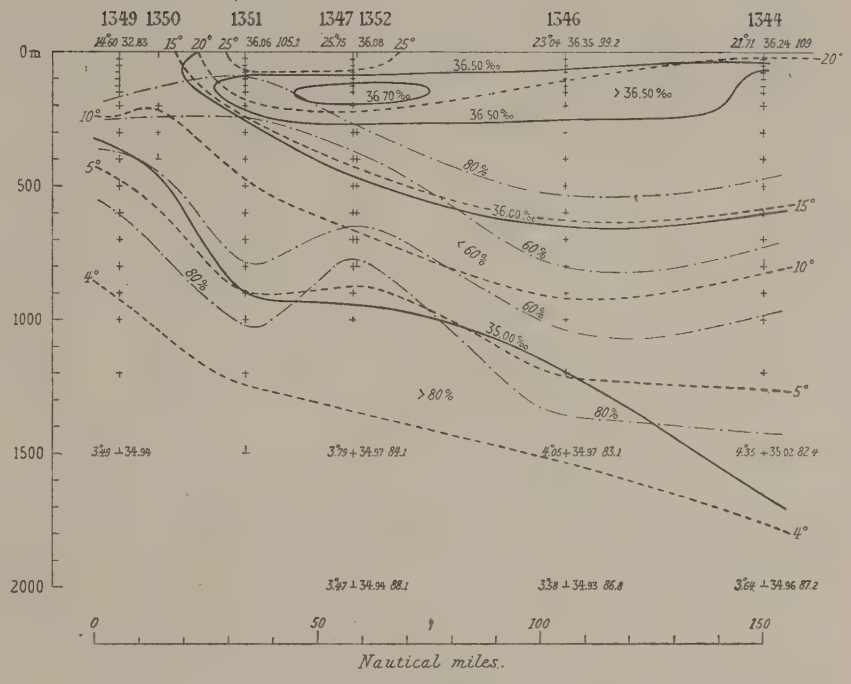

Fig. 11. Section IX a. — The western part of Section IX.

As was shown in dealing with sections at the West Indian Islands, the water of the Florida and Antilles Current is a mixture of the water from the Equatorial Current and the warm and saline surface-water at ca. 25° N. Lat., and on account of the intensive process of mixing which occurs during the movement, the water which is carried northwards by these currents, is relatively homogeneous at all events in the uppermost layers.

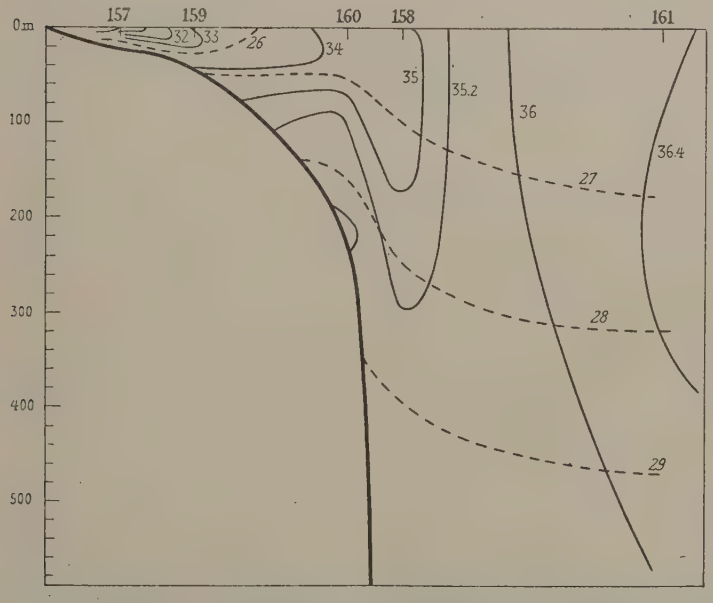

Fig. 12. Section from the mouth of Chesapeake Bay across the continental shelf after H. Bigelow (1917). The full drawn lines are isohalines, the dotted lines isodenses.

Summing up, the temperature, salinity and the oxygen contents of the Florida and Antilles Currents from the surface to a depth of 100 m. can be said to be resp. 24°, 36.3‰ and 96% (see p. 28). These statements are based on the observations made by the "Dana" at the West Indian Islands in the middle of February.

As noted on Table 2, page 14, we find under the surface layer a maximum salinity of 36.6‰ in the Florida Current (stations 1231—1237) at a depth of 150 to 200 m., together with a temperature of ca. 21.5° and oxygen contents of ca. 70%, and at similar depths in the Antilles Current (stations 1241 and 1242) a maximum salinity of about 36.8% with a temperature

Table 6.

Station		1349	1350	1351	1347	1352	1346	1344	1343	1342	1340	1339
Surface	Temp.	14.60	..	26.33	25.75	25.60	23.04	21.71	20.81	20.83	20.24	20.59
	Salinity	32.83	..	36.06	36.08	36.08	36.35	36.24	36.33	36.36	36.47	36.56
Intermediate water-layer with maximum salinity	Depth	..	..	125	150	..	100	50	75	50	75	0
	Temp.	..	..	22.70	22.65	..	20.30	19.27	18.86	19.86	19.09	20.59
	Salinity	..	..	36.67	36.74	..	36.58	36.51	36.51	36.49	36.53	36.56
	Oxygen	..	..	74.1	96.0	..	97.5	102.5	97.4	105.5	102.1	102.3
200 metres	Temp.	11.29	10.13	19.44	20.39	..	18.90	18.57	18.69	18.67	18.57	17.95
	Salinity	35.30	34.99	36.56	36.69	..	36.51	36.49	36.51	36.49	36.45	36.45
	Oxygen	66.9	76.8	66.9	84.6	..	97.2	95.1	97.0	99.1	94.2	83.7

of about 22° and oxygen contents of ca. 80 %. North of the Little Bahamas Banks the intermediate maximum salinity in both the Florida and the Antilles Current may be placed at 36.55 ‰, according to the section described by Wüst (see p. 12), and lastly there is a nearly uniform salinity of ca. 36.5 ‰ (p. 15) in the central part of the anticyclonic water movement in the western part of the Sargasso Sea, according to Bigelow's measurements from the surface down to about 300 m. depth.

For comparison with the hydrographic data given here for the Florida and Antilles Current, and for the western part of the Sargasso Sea, Table 6 shows some of the "Dana"s observations from the Norfolk section west of the Bermudas. With regard to the influence of the seasons it may be remarked that these observations refer to the middle of May.

It appears from Table 6 that water is carried on the surface over the stretch between stat. 1351 and stat. 1346 directly to the Norfolk section from the Florida Current and probably also from the Antilles Current. On the other hand, the high oxygen contents of 96 % at stat. 1347 in a water-layer of maximum salinity indicate, that this water-layer at any rate does not come from the intermediate layer in the Florida Current or Antilles Current. We may rather believe that water from the central region of the anticyclonic water-movement in the western Sargasso Sea likewise makes its influence felt at stat. 1347, in a similar manner to that earlier referred to on discussing the more easterly stations noted in the Table (p. 15).

It is possible that the oxygen contents in the depths here mentioned may be subject to comparatively abrupt and important changes, owing to the activity of living organisms, but on the other hand the low oxygen contents (74.1 %) in a layer with a maximum salinity at stat. 1351 indicate that the water has been brought here directly with the intermediate layer of the Florida or the Antilles Current.

SECTION X. — CAPE VERDE ISLANDS TO THE STRAITS OF GIBRALTAR.

As in the north-eastern part of section I we find below 3000 m. temperatures below 3° and salinities lower than 35 ‰ (see fig. 13). The oxygen contents in the water below 3000 m. show on the other hand a big difference in the two sections. In the northeastern part of section I the amount can be placed in round numbers at 80 %, whereas in section X at depth of 3000 m. about 60 % and at the bottom ca. 50 % and less.

The explanation of the difference between the bottom water in the two sections may be that the arctic bottom water at section X has only a slow movement and possibly also that the antarctic bottom water makes its influence felt. As shown by G. Böhnecke (1927) the antartic bottom water from the Brasilian depth penetrates over the ridge into the Guinea depth.

In depths of less than 3000 m. we find water-mixtures formed from the bottom-water and the

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same masses of water which have already been referred to in section I, namely, the water streaming out from the Mediterranean at ca. 1000 m. depth, the water-layer of low salinity from the south, at a depth of 800—1000 m., and lastly found in the southern part of section I, though to a less extent, water from a mixture of the Gulf Stream and the bottom-water present in the western Atlantic. These mixing conditions will be referred to more closely later; here, only some of the main features in the occurrence of these different kinds of water will be noted.

In the northern part of the section almost to the Canary Isles, we find in depths from 1200 m. to 3000 m. distinct mixtures of bottom-water and the water formed from the mixing at a depth of about 1000 m. of the outflowing Mediterranean Current and the Atlantic water present outside the Straits of Gibraltar. The conditions here are analogous with those described for the northeastern part of section I, but owing to the low oxygen contents of the bottom-water, we find that this mixing at a depth of 1500 to 2000 m. has given rise to an oxygen maximum, in spite of the fact that the oxygen of the Mediterranean is only ca. 70 %.

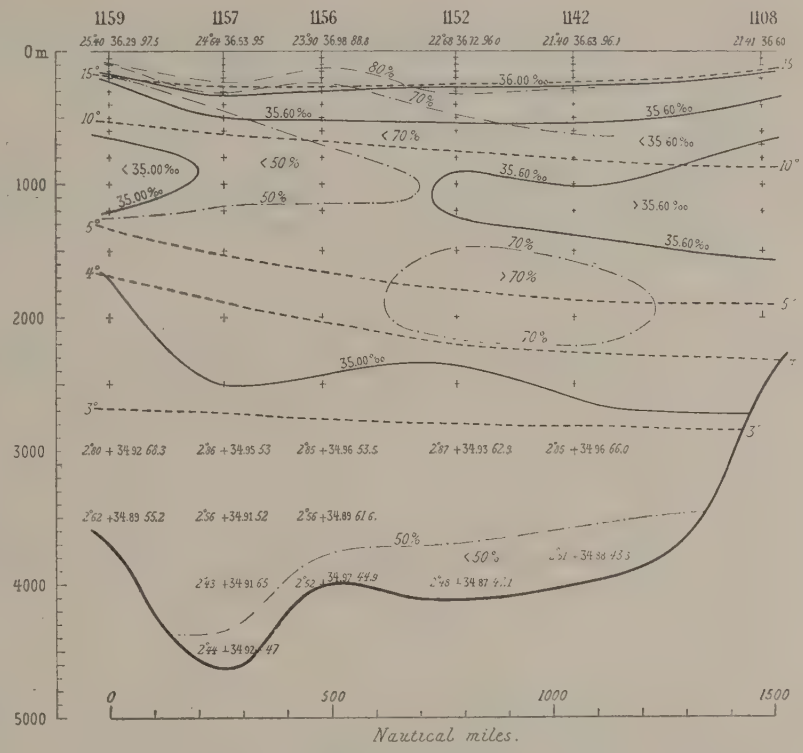


Fig. 13. Section X. — Cape Verde Islands to the Straits of Gibraltar.

South of the Canary Isles an infusion of the Mediterranean water is also to be detected on close examination, but in the southern part of the Section the water at a depth between 1000 and 3000 m. is mainly a mixture of bottom-water and the intermediate water-layer with low salinity from the south. The occurrence of the Mediterranean water so far as to the Cap Verde Islands is previously mentioned by Johs. Schmidt (1922).

The intermediate layer of low salinity is seen more especially in the southern part of the section, where at stat. 1159 at a depth of 800 to 1000 m. we find a salinity below 35 ‰. The layer in the southern part of the section is specially characterised by its low amount of oxygen. The oxygen minimum is however found at a somewhat less depth than the minimum of salinity, thus in the water-mixture which is formed from the mentioned intermediate layer at 800 to 1000 m. and the overlying water. At stat. 1159 we find the oxygen minimum at depths of 500—600 m. with the value 29.5 %, where the salinity is resp. 35.26 and 35.11 ‰, whilst the salinity minimum of 34.90 ‰ is at 800 m. depth. This indicates that both the water-layer of low salinity coming from the south and the overlying water-mixture are but slowly renewed.

Regarding the surface salinity of the section, we see that stat. 1156 has a maximum salinity of 36.98 ‰. Here we have to do with water which comes mainly from the central region, with high salinity on the surface, about 25° N. Lat. North and south of stat. 1156 there is also water of high salinity which may be considered to have been formed by the mixing of water of somewhat low salinity, coming from

the north, with water from the central region. Possibly also water ascending from the depths off the African coast has helped somewhat in the formation of the surface-water occurring in the section.

The watermasses mentioned only show however their influence a comparatively little way down at about 100 m. Between ca. 100 and 800 m. we find the characteristic mixture of surface-water from the central region at ca. 25° N. Lat. and the intermediate water of low salinity coming from the south.

SECTION XI. — CAYENNE TO THE CAPE VERDE ISLANDS.

The hydrographic conditions in depths greater than 3000 metres are in this section, fig. 14, nearly the same as in section X, in regard to temperature, salinity and oxygen contents. In accordance with the view set forth by Georg Wüst (1928) it must however be assumed that the bottom water in the Brasilian depth originates from the antarctic water and so the low temperature 2°,19, the low salinity 34.89 ‰ and the little amount of oxygen 47 % in 4500 meter at stat. 1171 are to be explained. Also in the eastern part of the section east of the Atlantic ridge the bottom water is influenced by Antartic water as mentioned under section X. The upper part of the here mentioned water below 3000 m must be assumed to consist mainly of Arctic bottom water, whose contents of oxygen have been diminished during a rather slow movement.

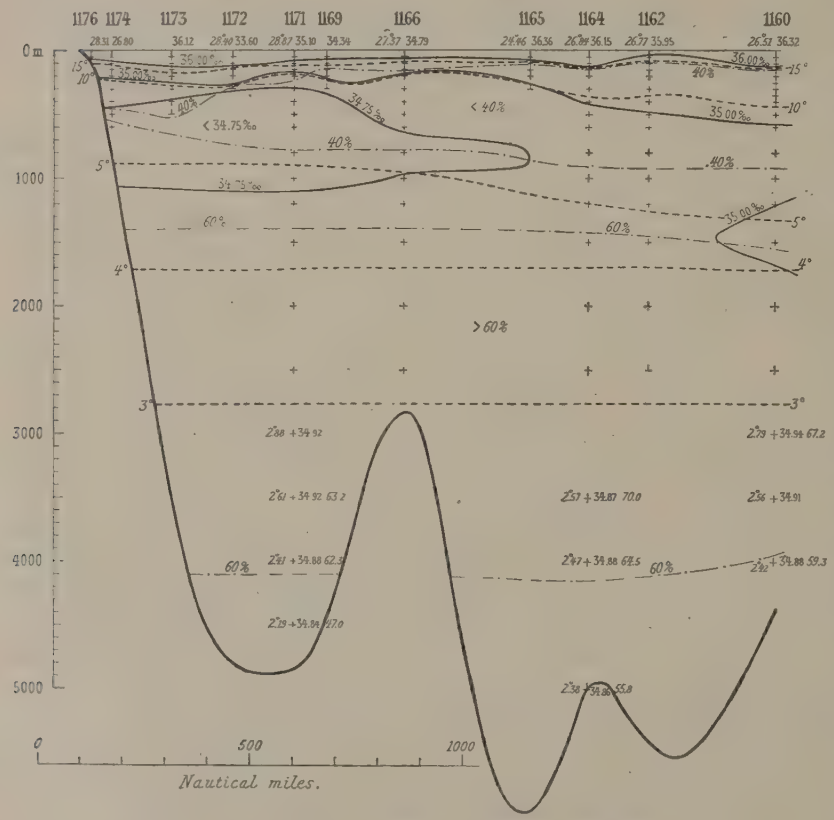


Fig. 14. Section XI. — Cayenne to the Cape Verde Islands.

The earlier mentioned water of low salinity coming from the south, at a depth of about 800 m., is very prominent in this section and most strongly in the southwestern part where the salinity descends to below 34.75 ‰. There is a small amount of oxygen in the water-layer, ca. 40 %, but — as also found in other places — the oxygen minimum lies in a higher layer than the depth of the lowest salinity.

Between 1000 and 3000 m. there is a water-mixture which is formed from the Atlantic bottom-water and the intermediate water-layer of ca. 800 m. depth.

On the surface the salinity shows great variations. It is highest in the north eastern part of the section, where the centrally situated surface-water of high salinity at about 25° N. Lat., makes its influence felt. From there the salinity diminishes in a southwesterly direction owing to the influence of the Equatorial Current, and at stat. 1169 reaches down to 34.34 ‰. At the following stations 1171, 1172 and 1173 the surface salinity is respectively 35.10 ‰, 33.60 ‰ and 36.12 ‰, and at the two Stations furthest

to the southwest, 1174 and 1176, it descends considerably below 30‰. These varying conditions of the surface salinity in the southwesternmost part of the section can be explained by reference on the one hand to the surface-water of high salinity coming from the south, partly to the influence of water from the coast to which the Amazon River contributes. The surface-water of high salinity coming from southern latitudes may be considered to arise from the region of ca. 20° S. Lat. off the coast of South America, where as in the region about 25° N. Lat. there is a salinity of 37‰ and more.

In the whole section we find high surface-temperatures of 27° to 28°.

Water of similar temperature and salinity as at the surface reaches only a short distance down, ordinarily less than 100 m. Under this surface-layer we find a water-mixture of similar qualities to those found in the corresponding depths of the sections lying more to the north, but it has a different origin. In the northern sections the water-mixture is — as mentioned before — formed of surface-water of high salinity at ca. 25° N. Lat. and intermediate water in 800 to 1000 meters north of the Equator, whereas the water-mixture in section XI is formed of surface-water of high salinity at ca. 20° S. Lat. and the intermediate water-layer of low salinity in 800 to 1000 meters depth which is present in these latter latitudes (see pag. 42).

The water-mixture here referred to in Section XI is comparatively limited in extent, ordinarily only reaching down to 200—300 m. From this depth down to 500—600 m. there is a water-mixture, which is formed by the just mentioned mixture and intermediate water at a depth of 800 to 1000 m. The last is different from the water that goes to form the mixture in depths from 100 to 200—300 m.

In the southwestern part of the section these various water-mixtures pass more evenly into one another.

In the following we shall more closely examine the different water-mixtures and show, among other things, that water from the region of high surface-salinity about 20° S. Lat. also makes its influence felt near the West Indian Islands.

3. SURVEY OF THE CHARACTERISTIC WATER-MASSES AND MIXTURES OCCURRING IN THE ATLANTIC BETWEEN THE EQUATOR AND 60° N. LAT. USING T-S DIAGRAMS

In the preliminary treatment of the material collected by the "Dana" Expedition given in the previous chapter, various comparatively uniform water-masses have been referred to which are found in the region mentioned from surface to bottom. These water-masses and the different water-mixtures formed from them will be the subject of investigation in this chapter, using for this purpose T-S diagrams such as have earlier been employed by Helland-Hansen (1918), A. Merz (1925), G. Wüst (1924), J. P. Jacobsen and Aage J. C. Jensen (1926), Lotte Möller (1926) and others.

It will be seen from the following that this method is specially suitable for a systematic treatment of the hydrography of the Atlantic, but it may probably be used also for other regions of the sea. In the opinion of the author it would often be advantageous to use this method instead of sections.

The main advantage of the method consists in this, that a homogeneous water-mass is characterized by a single point and that the mixture of two homogeneous water-masses is represented by points on a straight line connecting the points which represent the homogeneous water-masses.

The method may be employed in a graphic determination of the ratio of intermixing between the different water-masses, and it gives a convenient survey of the stability conditions between the different water-layers. Finally, the method gives an excellent control over the correctness of the measurements of temperature and salinity from the different depths, when these are sufficiently numerous.

To illustrate the use of the method in separating and characterizing water-masses of different origin, a T-S diagram is given in Fig. 15 a for the "Dana" stat. 1383 between the Azores and Iberian Peninsula (see Chart, Fig. 63).

In the diagram the temperature and salinity are plotted for the different depths and then curve I showing the connection between temperature and salinity has been constructed. On the curve are noted the depths in hectometres for most of the temperatures and salinities plotted in the figure.

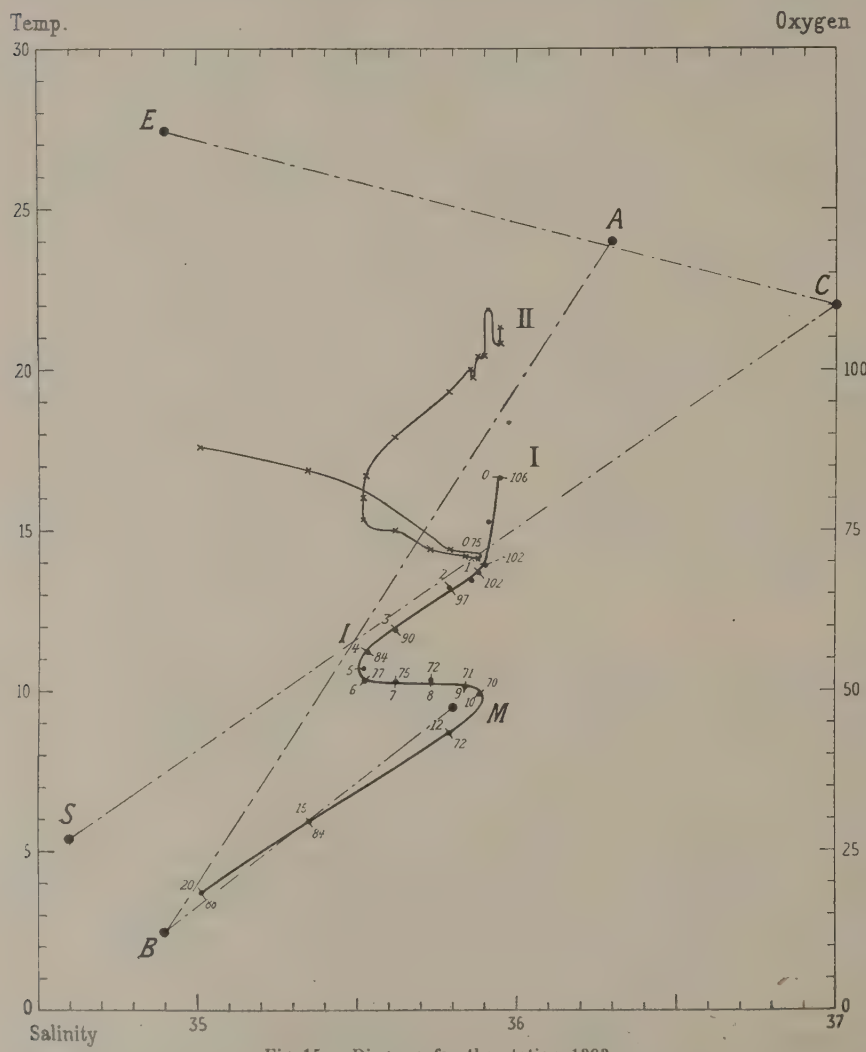


Fig. 15 a. Diagram for the station 1383.

It will readily be understood, that for a water-mass which has the same temperature and salinity through a series of depths the diagrams will show these collected in a single point. Two water-layers, each of which is homogeneous in temperature and salinity, but with different temperature and salinity for the two layers, will be represented by two points, on which are to be marked the depths through which the layers extend. If such layers are mixed with each other, without the intermixing reaching the uppermost boundary of the uppermost layer and the lowest boundary of the lowest layer, then the temperature and salinity of the water-mixture will appear in the diagram as a straight line joining the two points, which represent the original temperature and salinity of the water-layers, and temperatures and salinities will be found in the water-mixture corresponding to all points on the line named. When the mixing of the two water-layers has so far advanced that nothing remains of the original water-masses, or if a part of the water-mixture is carried to other places, the temperatures and salinities of the remaining water-mixture will retain their places on the straight line, but water-mixture in ratio corresponding to all points on the line will then not be found.

Even if the actual distribution of water-masses in the sea may lead to very complicated forms of diagrams for the various stations, we can often learn something from the conditions by means of T-S

diagrams, remembering, that water-masses homogeneous in respect to temperature and salinity are represented by single points and that different water-masses formed by mixing of two homogeneous water-masses will be found in the diagram lying in a straight line.

We exclude here the exchange of heat with the atmosphere, which naturally may produce divergences, so far as the uppermost layers are concerned. Further, the heat produced by mixing is omitted from consideration, as also the molecular heat conduction and diffusion, and likewise that the adiabatic change of temperature, caused by a change of level of the water-masses, is not the same for water of different temperatures and salinities. The influence of the conditions mentioned will certainly be of no importance in using the diagrams. But it might be advantageous to refer the temperatures to the pressure of 1 atmosphere, and to use these reduced temperatures for the construction of the diagrams. This has not been done however in the T-S diagrams given in this treatise.

If a mixture of three or more homogeneous water-masses occurs anywhere in the sea, the curves of the stations in the T-S diagrams will usually become crooked, but on account of the gradual transition between water-masses in the sea, the curves will ordinarily assume a regular course and we have therefore in such curves an excellent means of controlling the correctness of the observations, as HELLAND-HANSEN specially emphasizes.

In dealing with section I, in the north eastern part of which the stat. 1383 lies, the water-masses occurring from surface to bottom at this spot have already been mentioned, and for these and other water-masses within the region considered, a more detailled discussion will be given with the aid of T-S diagrams.

Here, in connection with the diagram for stat. 1383 as example of the use of the method, we shall only refer to 3 sorts of water which in regard of temperature and salinity are relatively homogeneous. The approximate position of these water-layers are shown on the Chart, Fig. 16.

(1). Water found in great depths in the North Atlantic. The temperature and salinity of this water are placed at resp. 2.5° and 34.90 ‰. This water is called B-water and is in the diagram denoted by the point B ("Bottom-water").

(2). Water of high salinity lying centrally in or near the surface at ca. 25° N. Lat., characterized by a temperature of 22° and a salinity of 37 ‰. This is marked as C-water and is in the diagram denoted by the point C ("Central-water").

(3). The intermediate water-layer at a depth of ca. 1000 m. mainly off the Spanish coast. The water is a mixture of the outflowing water of the Mediterranean and the surrounding water of the Atlantic, characterized by a temperature of 9.5° and a salinity of 35.8 ‰; it is called M-water; in the diagram denoted by the point M ("Mediterranean-water").

We see from the diagram Fig. 15a that the T-S curve for depths from 1000—2000 m. follows the line B M rather closely. But this is not exactly the case, and divergences like these which occur in this case have to be reckoned with on account of the uncertainty in the definitions of the water-masses which are regarded as homogeneous, here B-water and M-water. Taking account of this uncertainty we may still assume, that the water-masses represented by points on the curve for depths between 1000 and 2000 m. have arisen from mixtures of B-water and M-water. The relation between the masses of B-water and M-water, which enter into a distinct water-mixture, can be found by the relation between the distances from the point on the curve which represents the water-mixture to the points M and B. We thus find that in 1500 m. depths there are almost equally great masses of B-water and M-water, and in 1200 m. depth only ca. 10 % B-water, whilst the remainder is almost entirely M-water, though somewhat different from the previously defined.

Between 75 and 400 m. also the straight course of the T-S curve shows that there is a water-mixture in these depths which may have arisen from two homogeneous water-masses in similar fashion

to the water-mixture between 1000 and 2000 m. As will be shown later, this is evidently the case, but in such a way that the mixing has taken place between the above mentioned C-water, in the diagram marked with point C, and water-masses which have arisen by mixing within the region mentioned.

The course of the curve from the surface down to 75 m. might suggest an infusion of the mixture in 75 m. with surface-water of a special kind, but we must take into account here the exchange of heat with the atmosphere.

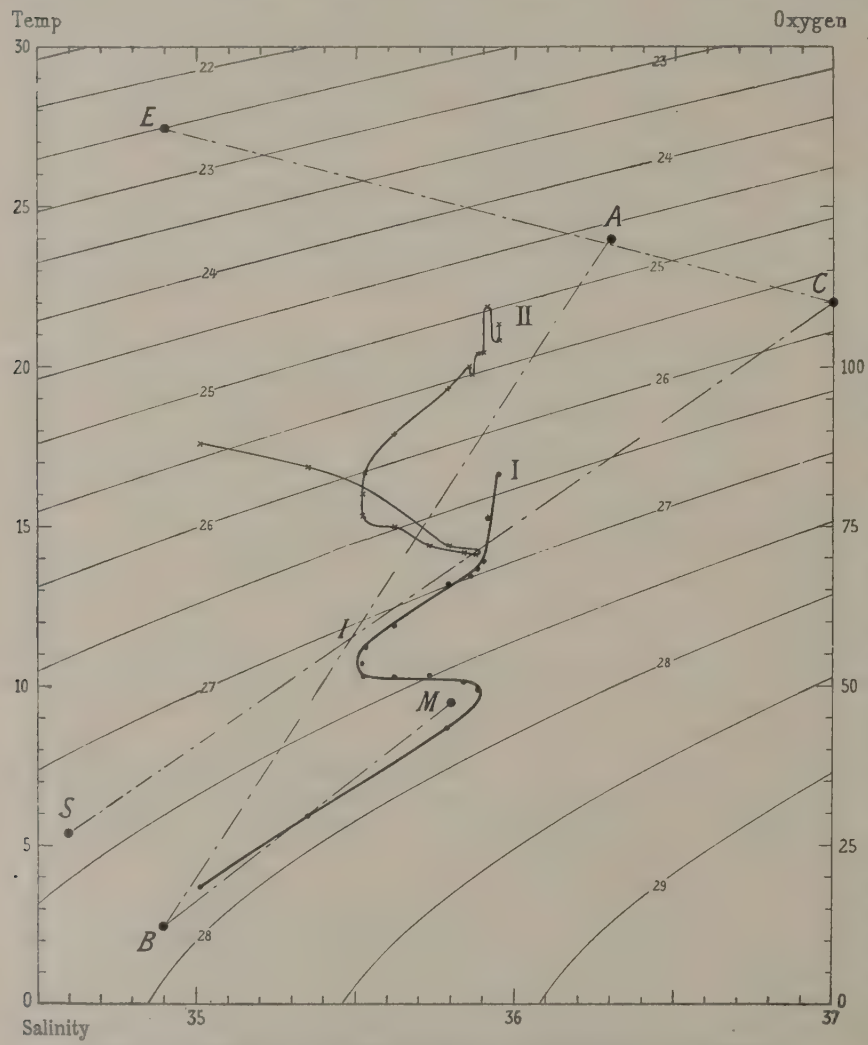


Fig. 15 b. Diagram for the station 1383. The curves 22, 23 etc. are isodenses.

In Fig. 15 b, which like Fig. 15 a shows the T-S curve for stat. 1383 but without data for the depths and oxygen contents, the isodense curves are drawn for resp. $\sigma_t = 29.0$, $\sigma_t = 28.5$ etc. With help of these curves we obtain a good picture of the stability conditions for the different water-masses, which are represented by the T-S curve for the station.

In this way we see that the mixture of B-water and M-water between 1000 and 2000 m. follows very nearly the isodense-curve for $\sigma_t = 28.0$, so that the water in the depths referred to is of but little stability. From 1500 to 2000 m. the curve deviates somewhat from the curve for $\sigma_t = 28.0$, but this may be accounted for chiefly by the adiabatic rise of temperature which occurs in descending water-masses, owing to increase of pressure in the deeper layers. According to W. Ekman this rise of temperature amounts to 0.14° for water with a salinity of 35.9‰ and a temperature of 10° in a descent from 1000 to 2000 m. As noted before (p. 25), it would be more rational to use temperatures reduced to the pressure of one atmosphere in the construction of the diagrams. The changing directions for the other parts of the curve show that the stability changes with the depth and that it is greatest in the uppermost 75 m., where apparently a heating from the surface has occurred.

In the two bends of the curve at ca. 500 and at ca. 1000 m. the stability is relatively great, because the curve in these depths runs almost at right angles to the isodense curves, but when we con-

sider how little the temperature and salinity of the water vary within a water-layer of considerable thickness, the stability is yet small within a given depth-interval, corresponding to the mixings which evidently occur in these depths.

It is easily understood that a mixing of water-masses, which lie between for example 200 and 800 m., will have such an effect on a curve representing the temperature and salinity of the water-masses after the mixing, that it will have a less sharp bend than the original curve and thus lie to the right of this.

If such a change occurs in the course of a certain time at the spot represented by the curve of the station, without any other water being brought into the depths considered, we can determine from the position of the two curves relative to one another, the characteristic constant for the mixture, the "mixing coefficient". For this J. P. JACOBSEN (1927) as elsewhere given a simple graphic method by means of which the determination is made by the measurement of a piece of line defined by the curves.

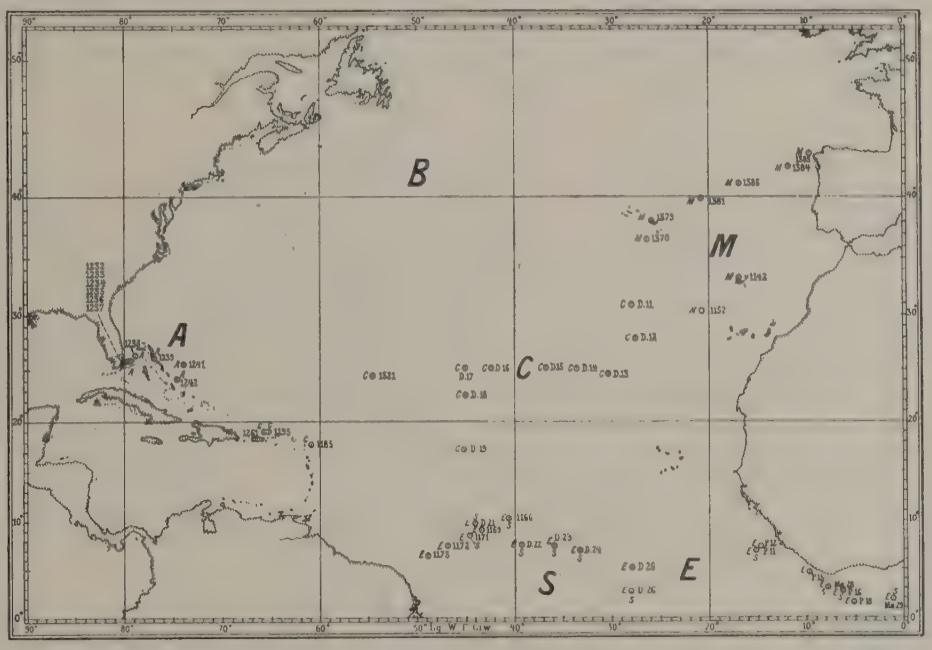


Fig. 16. Chart showing the position of different sorts of water occurring in the Atlantic. The letters *A*, *B*, *C*, *S*, *M* and *E* refer to the denominations of the water-sorts (see p. 25—32).

The oxygen can naturally be coordinated e. g. with the salinity in the same manner as the temperature. In this way a curve is obtained for the station in question as is shown with curve II in Figs. 15 a and 15 b. The observations on that curve are marked with × and can thus be referred to the depths on curve I. We can see from this curve, for example, that the oxygen contents are very low at a depth of 800—1000 m., ca. 72 %, where we find a relatively stable water-layer above the mixture of B-water and M-water.

In using T-S diagrams in the following the amount of oxygen is however noted at those points on the curves which mark the different depths, as has also been done in Fig. 15 a. This procedure is chosen so as not to overcrowd the figures.

I may now proceed to a closer description of the water-masses in the Atlantic, between the Equator and ca. 60° N. Lat., which may be characterized as fairly homogeneous in regard to temperature and salinity.

Besides the already mentioned water-masses B-, C- and M-water, we have chiefly to note the A-water which is carried northward with the Antilles and Florida Current along the east coast of America under the name of Gulf Stream, the S-water ("South-water") which occurs directly north from the Equator as an intermediate layer in ca. 800 m. depth, and the E-water ("Equatorial-water") which is carried westward by the north and south Equatorial Currents in the uppermost layer.

The A-water here referred to is in reality itself a mixture, mainly of C-water and E-water, but on account of its relatively uniform temperature and salinity and its decisive importance for the hydrographical conditions in regions of wide extent, there is good reason to give it a special designation.

In the Fig. 16 are plotted the stations, from which observations have been used for the determinations of the temperature, salinity and oxygen of different sorts of water. The stations are marked according to the sort of water they have been used for.

Here we shall note the characteristic hydrographical data for the 6 main sorts of water resp. A-, B-, C-, S-, M- and E-water.

1) *A*-water (Water from the Antilles Current and the Florida Current): T = 24°, S = 36.3 ‰, O_2 sat. = 96 %.

The A-water is defined as water from the Antilles and the Florida Current down to 100 m. depth.

In calculating the temperature, salinity and saturation of the oxygen contents for the A-water, the observations of the "Dana" stations 1232—1238 (Florida Current) and 1239, 1241 and 1242 (Antilles Current) have been used (see Table 7 and Fig. 16).

Table 7.
The Florida Current.

Depth m	0			25			50			75			100		
Stat.	Temp.	Salin.	Oxyg.	Temp.	Salin.	Oxyg.	Temp.	Salin.	Oxyg.	Temp.	Salin.	Oxyg.	Temp.	Salin.	Oxyg.
1232...	24.78	36.18	98.0	24.91	36.17	94.7	24.89	36.17	97.5	24.78	36.34	94.7	24.56	36.27	94.5
1233...	23.73	36.17	96.6	23.34	36.18	97.4	22.81	36.17	97.2	22.35	36.18	93.9	14.91[1])	35.61[1])	63.5[1])
1234...	24.57	36.06	97.7	24.36	36.08	96.7	23.89	36.17	97.0	23.26	36.40	86.7	22.10	36.27	92.1
1235...	24.92	36.06	97.8	24.86	36.06	98.4	24.86	36.06	97.3	23.99	36.29	91.9	22.87	36.17	95.2
1236...	24.83	36.08	98.0	24.83	36.08	97.7	24.83	36.08	96.9	24.80	36.09	96.5	23.76	36.35	92.5
1237...	24.80	36.17	97.7	24.81	36.17	98.0	24.82	36.17	97.3	24.57	36.17	94.9	24.26	36.35	91.4
1238...	23.50	36.45	97.8	23.50	36.45	97.6	23.52	36.51	97.2	23.52	36.51	94.2	23.52	36.51	96.0
Mean..	24.45	36.17	97.7	24.37	36.17	97.2	24.23	36.19	97.2	23.90	36.27	93.3	23.51	36.32	93.6

[1]) These observations have not been included in the mean values below

The Antilles Current.

Depth m	0			25			50			75			100		
Stat.	Temp.	Salin.	Oxyg.	Temp.	Salin.	Oxyg.	Temp.	Salin.	Oxyg.	Temp.	Salin.	Oxyg.	Temp.	Salin.	Oxyg.
1239...	23.42	36.51	95.4	23.42	36.51	95.4	23.35	36.51	96.6	23.22	36.51	95.8	23.17	36.56	95.0
1241...	23.92	36.67	97.8	23.86	36.67	..	23.66	36.67	97.2	23.54	36.69	..	23.41	36.69	93.7
1242...	24.13	36.64	96.8	24.11	36.62	..	24.07	36.62	96.6	24.07	36.62	..	23.98	36.65	93.7
Mean..	23.82	36.61	96.7	23.80	36.60	95.4	23.69	36.60	96.8	23.61	36.61	95.8	23.52	36.63	94.1

For the uppermost 100 m. we find from the Table the following mean values for the Florida Current and the Antilles Current:

Florida Current: Temperature 24.09° Salinity 36.22 ‰ Oxygen 95.8 %.
Antilles — : — 23.69° — 36.61 ‰ — 95.8 %.

Accepting Wüst's calculation, that the Florida Current is twice as strong as the Antilles Current, the values in round numbers of the temperature (T), salinity (S) and oxygen (O_2 sat) for the A-water are as given above.

2) *B*-water ("Bottom-water"): T in situ = 2.5°, S = 34.90 ‰.

The B-water is defined as bottom-water in the North Atlantic. According to Nansen it comes chiefly from a region S. E. of Greenland, where it sinks down from the surface to the bottom owing

to its greater specific weight. As mentioned before in dealing with the different sections, we find this water again in depths of more than 3000 m. in nearly unmixed condition all over the Northern Atlantic where the depth conditions permit it to penetrate.

The summary below, Table 8, gives the temperatures, salinities and oxygen contents measured by the "Dana" at 3000 m. and greater depths, at stations from the western and eastern part of the Atlantic with a depth of ca. 4000 m. and more.

We see that the salinity varies only to a small degree with depth and place. The temperature diminishes somewhat towards deep water, but for the same depth is but little different from place to

Table 8.

Western Deep

Stat....	1342			1356			1335			1261			1185			1181			1171		
Depthm	T	S	O_2	T	S	O_2	T	S	O_2	T	S	O_2	T	S	O_2	T	S	O_2	T	S	O_2
3000...	3.01	34.94	83.4	2.91	34.93	81.8	2.91	34.94	..	2.76	34.96	81.9	2.76	34.93	73.3	2.42	34.91	73.3	2.88	34.92	..
3500...	2.68	93	83.1	63	92	81.3	68[1]	89[1]	78.3[1]	53	92	81.3	44	92	73.6	37	91	68.5	61	92	63.2
4000...	46	92	82.8	39	90	80.8	40[3]	88[2]	75.1[3]	44	92	..	39	91	73.6	30	91	74.8	41	88	62.3
4500...	37	88	80.7	27	86	79.6	28	88	77.9	..	94	80.5	36	92	73.1	..	..	..	19	84	47.0
5000...	38	88	79.1	14	85	78.8	22	88	77.0	2.55	94	..	..	..	..	..	..	..	..	..	..
5500...	..	..	..	15	85	77.3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Eastern Deep

Stat....	1387			1142			1152			1156			1157			1160			1164		
Depthm	T	S	O_2	T	S	O_2	T	S	O_2	T	S	O_2	T	S	O_2	T	S	O_2	T	S	O_2
3000...	2.86	34.97	76.2	2.85	34.96	66.0	2.87	34.93	62.9	2.85	34.96	53.5	2.86	34.95	53	2.79	34.94	67.2	..	..	..
3500...	65	91	75.9	..	..	..	..	..	..	56	89	61.6	56	91	52	56	91	..	2.57	34.87	70.0
4000...	54	91	78.2	2.51[3]	34.88[3]	43.3[3]	2.48	34.87	47.1	52	97	44.9	43	91	65	42	88	59.3	47	88	64.5
4500...	56	89	78.9	..	..	..	..	..	..	..	..	..	44	92	47	..	..	..	38	86	55.8

[1]) Depth 3420 m. [2]) Depth 3920 m. [3]) Depth 3800 m.

place. For the greatest depths the temperature is yet about $^1/_{10}°$ higher in the eastern part than in the western. The amount of oxygen diminishes somewhat with the depth and is very different at the northern and southern stations. With regard to the oxygen contents, however, it should be mentioned that some uncertainty prevails in the observations owing to the possibility that the metal parts of the waterbottle absorb oxygen, as noted on p. 5.

In a depth of 4000 m. the middle values of the temperature and salinity are resp. 2.41° and 34.89‰ in the western, and 2.48° and 34,90‰ in the eastern part. In the same depth the oxygen contents for the northern stations amount to ca. 80‰ and for the southern ca. 60‰.

It appears from this that we can not consider the bottom-water as homogeneous. As mentioned before (p. 22) also the antarctic water is of some influence at the southernmost stations in Table 8. Yet the temperature and salinity of the bottom-water mixed with the upper layers can be regarded as constant and for these we take the mean value at 4000 m at the stations mentioned in Table 8. Then we have in round numbers T = 2.5° and S = 34.90‰.

We have to remember that a temperature of 2.5° in 4000 m. reduced to the surface is ca. 2.1° and for a water-mixture between the surface and 4000 m. in which the bottom-water is a constituent, we must allow for temperatures of the bottom-water between 2.1° and 2.5°. As the mixture of water which

contains bottom-water is usually found at very great depths, we have for the temperature of the bottom-water constituent to take a temperature near the temperature in situ 2,5°, and it does not make any great difference that in the T-S diagrams given later the temperature in situ is used in place of the reduced temperature.

3) *C*-water ("Central-water"): T = 22°, S = 37.00‰, O_2 sat = 98%.

C-water is defined as the warm salt water which is found at 100 m. depth in a belt between the Canary Isles and Porto Rico. It comes mainly from the central warm and salt surface-water at ca. 25 °N. Lat. as mentioned before.

In calculating the temperature, salinity and oxygen of the C-water, besides the observations from the "Dana", observations from the German Antarctic Expedition, 1911—12, have also been used. The stations are noted on the Chart, Fig. 16. Table 9 below indicates temperature, salinity and oxygen in 100 metres at the stations quoted. In the figure and in the table the German stations are noted with D.

Table 9.

Station	Temperature °C	Salinity ‰	Oxygen %
D11	18.98	36.75	100
D12	19.90	37.06	99
D13	20.35	37.05	99
D14	20.92	37.00	95
D15	21.83	37.17	98
D16	21.37	37.07	96
D17	21.13	36.90	98
D18	21.63	37.09	95
1321	22.55	37.23	107.8
1261	23.89	36.89	94.5
1195	26.10	36.85	96.0
1185	24.91	37.11	100.4
D19	23.56	36.82	93
Mean	22.09	37.00	97.8

As round numbers for the values of the temperature, salinity and oxygen we have resp. 22.0°, 37.00% and 98%. We see that the water under consideration only approximately can be regarded as homogenous and that especially the temperature in the western part of the region is higher than in the eastern.

4) *S*-water. ("South-water"): T = 5.4°, S = 34,60‰, O_2 sat = 40%.

The S-water is defined as an intermediate waterlayer in depths of 700—800 m. between the Equator and ca. 10° N. Lat., the salinity of the layer being a minimum in regard to the depth.

In calculating the temperature, salinity and oxygen of this water, as well as the depth in which it is normally found, besides the observations from the "Dana" we have the observations from the German Antarctic Expedition, 1911—12, the German "Möwe" Expedition 1911, and the German "Planet" Expedition, 1906—07. The stations are noted in the Chart, Fig. 16 and in Table 10, where the German stations are marked with D, Mö and P respectively.

The procedure in regard to the determination of the related values for the temperature, salinity, oxygen contents and depth has been, to draw T-S diagrams with data of the depth for the stations in

question, and from these to read the depth, temperature and salinity, where the salinity was a minimum in a depth of about 700 m. By interpolation was found the oxygen corresponding to the data noted. As shown in Table 10 we find:

Table 10.

Station	Temperature °C	Salinity ‰	Oxygen %	Depth m.
1166	5.73	34.65	40.1	800
1171	5.5	34.67	40	700
Mö 28	5.2	34.53	..	700
Mö 29	5.5	34.45	..	600
D 21	5.5	34.63	29	800
D 22	5.5	34.60	42	700
D 23	5.2	34.62	..	750
D 24	5.5	34.60	40	750
D 26	5.2	34.48	45	750
P 11	5.3	34.60	..	800
P 16	5.0	34.50	42	750
Mean	5.4	34.57	40	736

As values in round numbers for the temperature, salinity and oxygen we have resp. 5.4°, 34.60‰ and 40%. The mean depth for the water-layer is calculated at about 750 m.

We see that the oxygen contents of 29% at stat. D 21 are lower than elsewhere. This is probably due to chance, the nearest station 1171 of the "Dana" Expedition showing the normal oxygen contents for the water-layer. That the oxygen is relatively high at stat. D 26, is easily explained by its southern situation.

5) *M*-water (»Mediterranean-water«): T = 9.5°, S = 35.80‰, O_2 sat = 68%.

The M-water is defined as an intermediate water-layer at depths of ca. 1000 m. with a maximum salinity in regard to depth in the region between the Azores and the Straits of Gibraltar. It is characterized by the large admixture of Mediterranean water.

In calculating the temperature, salinity and oxygen contents of the M-water and the depth in which it is normally found, the observations from the "Dana" Expedition at stat. 1385, 1384, 1383, 1381, 1379, 1370, 1142 and 1152 have been employed (see Fig. 16).

The method for the determination of related values for temperature, salinity, oxygen and depth has been to draw T-S diagrams for the stations, with data regarding the depths and the oxygen contents, and then to read from these the depth, temperature, salinity and oxygen, where the salinity showed a distinct maximum at a depth of ca. 1000 m. As shown in Table 11 we find:

Table 11.

Station	Temperature °C	Salinity ‰	Oxygen %	Depth m.
1385	10.8	36.10	70.6	1100
1384	10.2	35.94	70.	1050
1383	9.8	35.90	71.	1050
1381	9.27	35.79	70.5	1000
1379	9.1	35.55	70.5	850
1370	9.37	35.71	68.8	1000
1152	9.0	35.71	61.	1050
1142	8.5	35.72	65.	1250
Mean	9.51	35.80	68.4	1044

In round numbers the temperature, salinity and oxygen may be placed at 9.5°, 35,80‰ and 68% resp. As approximate value for the depth we have 1000 m. It will be seen, that the water at the stations mentioned is somewhat variable, especially the oxygen contents at stat. 1152 are low. This is undoubtedly due to a stagnation of the water which spreads southward from the Straits of Gibraltar, whereas the water which goes northward keeps on moving in a northerly direction.

6) *E*-water ("Equatorial-water"): T = 27.4°, S = 34.90‰, O_2 sat. = 98%.

The E-water is defined as surface-water near the Equator. In calculating the temperature, salinity and oxygen contents for this water, we have used observations from the German "Deutschland" Expedition 1911—1912, "Möve" 1911 and "Planet" 1906—1907, besides the observations of the "Dana". The stations from these expeditions are noted on the Chart, Fig. 16 and in Table 12. The German stations are marked, with D, Mö and P. resp. As shown in Table 12 we find for the surface:

Table 12.

Station	Temperature °C	Salinity ‰	Oxygen %
1166	27.37	34.79	99
1169	28.48	34.34	
1171	28.87	35.10	101.1
1172	28.40	33.60	
1173	27.53	36.12	
D 21	26.53	35.75	99
D 22	26.86	34.39	97
D 23	27.22	34.79	
D 24	27.16	35.07	99
D 25	26.83	35.55	98
D 26	25.72	35.29	98
P 11	27.8	34.65	99
P 12	27.8	34.76	
P 15	29.2	33.79	
P 16	28.5	35.11	94
P 18	28.4	34.94	92
Mö 28	25.0	35.05	
Mö 29	25.3	34.96	
Mean	27.39	34.89	97.6

In round numbers the temperature, salinity and oxygen are resp. 27.4°, 34.90‰ and 98%.

As will be seen, the water in this region is somewhat heterogeneous. It includes water from the northern and southern Equatorial Currents and also water from the adjacent region towards the north with salter water.

The stations 1174 and 1176 are not included in the foregoing calculation, owing to the fact that water of very low salinity, resp. 26.80‰ and 28.31‰, was found at these stations. These low values for the salinity are due presumably to the influence of the Amazon River. That the oxygen contents on the surface at Stat. P 16 and P 18 are so low, is due without doubt to mixing of surface-water with underlying water of poor oxygen contents. Already at a depth of 100 m. we find the oxygen minimum at Stat. P 18, namely 43%.

The 6 different sorts of comparatively homogeneous water-masses thus defined, on mixing together, give to the part of the Atlantic here considered its hydrographical character. The mixing of two or more

of the water-masses usually proceeds in such a way, that a mixture of water arises of very variable composition, but in a few cases a mixture may also be formed with fairly uniform temperature and salinity.

This is the case with water-masses which occur at about 100 down to 600 m. off the coast of south-west Europe. According to observations by LE DANOIS (1924) HELLAND-HANSEN and NANSEN (1926), MATTHEWS (1911), J. N. NIELSEN (1907) and others, the temperature and salinity of the water named may be placed at ca. 11° and ca. 35.5‰.

In this connection we may cite again (p. 18) the relatively homogeneous water from the surface down to ca. 300 m. found west and south-west of the Bermudas with temperature ca. 19° and a salinity of 36.5‰, and of course a closer investigation of the water-masses occurring within such a large district as that dealt with here, may extend beyond the consideration of the 6 main forms.

For the present treatment of the hydrographical conditions, we shall yet in the main only deal with the six water-masses and mixtures directly composed of them.

To illustrate what different sorts of water-mixture may be formed by the 6 main forms of homogeneous water, these are marked in Fig. 15 a and 15 b, with their temperature and salinity as already described for three of these main forms. The straight lines joining the separate points indicate the temperature and salinity for the kinds of mixtures which can be formed by the main forms. As we shall see later, within the region considered we find important masses of water-mixtures which are noted by the broken lines (—·—·—·—), these water-mixtures not being combined with other waters.
According to the figure the A-water can be regarded as a mixture of C-water and E-water. The curved lines in Fig. 15 b, are isodense curves for the pressure of 1 atmosphere.

A consideration of the situation of the straight lines in Fig. 15 b in relation to the isodense-curves, shows certain pecularities in the stability of the water masses relative to one another.

The B-water being the heaviest seeks its way to the bottom and pushes in under the other water-masses which may occur there. The M-water, on account of its high specific gravity will penetrate between the bottom-water and the upper layers, and, owing to the relatively little difference in gravity between B-water and M-water, their mixing will proceed somewhat easily and the water-mixture will have a relatively low stability, as earlier mentioned.

S-water has a smaller specific gravity than a mixture of B- and M-water and also a specific gravity smaller than a mixture of A-water and B-water in which the last-named composes more than about the two thirds.

Together with the geographical conditions this has the effect that no water-mixture occurs which is formed of S-water and M-water alone or very seldom of S-water and B-water alone.

On the other hand, owing to the geographical conditions and the relatively small difference in specific gravity between S-water and C-water, the various kinds of water-mixtures arise which are represented by the line S-C over a large area of the southern part of the North Atlantic, between ca. 100 and 1000 metres depth.

The C-water owing to its low specific gravity is found in unmixed condition on or near the surface. The same is the case with E-water. Between these two kinds of water arise different mixtures, which likewise are found on or near the surface and which may suitably be designated surface-mixture. The mixing takes place especially in West Indian waters, and as a result we have the water defined as A-water in the Florida and Antilles Current.

In spite of the fact that an exchange of heat with the atmosphere may be assumed to occur at the same time as the mixing of C-water and E-water, the point which represents A-water lies almost on the line C-E. Apart from chance the reason may be that the change of heat between water and air is less in the equatorial part of the Atlantic than in the northern.

Special interest is attached to the mixture of A-water and B-water in the Newfoundland region, in relation to the adjacent mixture of C-water and S-water.

As shown in Fig. 15 a and b the two lines A-B and C-S cross each other. The point of bisection is noted by J, and the water represented at this point, with a temperature of 11.5° and salinity of 35.5 ‰, may thus have arisen either from C-water and S-water or from A-water and B-water. In both cases this water-mixture has the same specific gravity (σ_t = 27.1). It may provisionally be named J-water.

We may now distinguish between:

(1) Mixture of A-water and B-water with a salinity greater than J-water.

(2) Mixture of S-water and C-water with a salinity greater than J-water.

(3) J-water.

(4) Mixture of S-water and C-water with a lower salinity than J-water.

(5) Mixture of A-water and B-water with a lower salinity than J-water.

Most of the (1) sorts of water-mixture are of less specific gravity than those under (2) and for both groups the specific gravity is less than the J-water. The (4) and (5) sorts of water-mixture all have greater specific gravity than the J-water, and those under (5) on the whole a greater specific gravity than those mentioned under (4).

When all these sorts of water-mixture occur in the same geographical locality they will mainly arrange themselves in layers in the order noted. Such an occurrence might possibly take place south of the Newfoundland region, but the existing hydrographical conditions will soon produce a change in this condition, if it should occur.

In the first place the surface-water of but low salinity from the Newfoundland region, together with the (1) water-mixtures will produce a surface-water with a north and east-going movement, and this again, at its southern boundary, together with the (2) water-mixtures will create a surface-water with less northerly and more easterly movement.

At about 40° N. Lat. the surface-water formed in this manner in the eastern part of the Atlantic has approximately the same temperature and salinity as noted in the diagram, Fig. 15 a and 15 b under point J, namely 11.5° and 35.5 ‰, so that advantageous conditions are thus given for intermixture in a vertical direction between the surface-water mentioned and the water provisionally called J-water.

Together with the vertical intermixture produced by winter-cooling and strong movements, this explains why in the eastern part of the Atlantic off the south-west of Europe we find relatively homogeneous water-masses down to ca. 500 m., with a temperature of 11.5° and a salinity of 35.5 ‰. This water may thus be of different origin, namely:

(1) the surface-water referred to,

(2) the mixture of A-water and B-water, and

(3) mixture of C-water and S-water.

A differentiation of these different kinds of water cannot be made, at least not directly, from their temperature and salinity, but the oxygen contents may to a certain degree be used for that purpose.

In the following the designation J-water is employed for all the kinds of water with the temperature and salinity 11.5° and 35.5 ‰.

With reference to the sorts of water-mixtures cited under (4) and (5) we have to note, that the differences in specific gravity are relatively small. We may therefore expect a considerable mixing between them, which also has proved to be the case.

For the sake of brevity we shall henceforward call the mixture of A-water and B-water, AB-water, the mixture of C-water and S-water, CS-water, etc.

As shown in the chart, Fig. 63, that part of the Atlantic dealt with is divided into various areas marked I-XXIV. The boundaries of the areas have been chosen in such a way that the water-masses occurring in each are of somewhat the same composition and extent, or so that each area may show the characteristic transitional forms between the water-masses occurring.

Before discussing the hydrographical conditions in these separate areas, examples of the charac-

teristic mixtures between the main forms of the water-masses occurring may be shown with the aid of TS diagrams. At the same time a survey of the geographical distribution of the various sorts of water-mixtures may be given.

For this purpose we shall first refer to selected stations on the stretch from the Azores over the Sargasso Sea to Cape Norfolk on the coast of America, along with stat. 1383 between the Azores and Spain which has already been used as example.

The selected stations are, as can be seen from Fig. 17: 1369, 1367, 1365, 1362, 1322, 1356, 1342, 1347 and 1349. With exception of stat. 1356 all lie in the sections I and IX earlier referred to. (see Fig. 1).

Considering again the condition at stat. 1383, a possible interpretion of the TS-diagram, Fig. 15 a and 15 b, might be, that between 75 and 500 m. a mixture of S-water and C-water occurs, but as this mixture should contain in a depth of 150 m. about half of each of these water-masses, the oxygen contents in this depth should be ca. $\frac{40+98}{2} = 69\,^0/_0$. In reality the water at 150 m. is found to be almost saturated with oxygen, and cannot therefore be a mixture of S-water and C-water. The true explanation may be supposed to be that the water-mixture between 75 and 500 m. is CJ-water. The J-water may be formed in the three ways mentioned (p. 34), but the AB-water probably contributes the main part. This is due to the position of stat. 1383 in relation to the Atlantic current system. (See the isobar charts Fig. 53 to 55). The oxygen contents of the J-water at stat. 1383 are admittedly only ca. $80\,^0/_0$, but even if the AB-water has originally been saturated with oxygen during its formation in the Newfoundland region, on its way to the area where stat. 1383 is situated, it may have had its oxygen diminished to about $80\,^0/_0$. On the other hand, there is the possibility that J-water with lower oxygen contents than ca. $80\,^0/_0$ may have had its oxygen increased on the coast of Europe by the aeration arising from breaking against the continental shelf. Possibly the CS-water has thus helped in the formation of this J-water.

Between 500 and 1000 m. we have the JM-water. The stability of this is considerably greater than the stability of the water above and below and, as will be seen from Fig. 15 b the distribution of the specific gravity is such that practically only unmixed B-water can penetrate under it, and only water of less specific gravity than J-water over it. The JM-water in 500—1000 m. is specially characteristic of stat. 1383 and other stations in this area.

Stat. 1369: 35° 44′ N. Lat. 29° 33′ W. (Fig. 17) south-west of the Azores, observations down to 2500 m.

We find at this station conditions similar to those at stat. 1383. From 2500 to about 1000 m. we find chiefly MB-water and from 600 or 700 m. to the surface JC-water with special conditions in the uppermost 100 m., possibly due to atmospheric influence. At this station the intermixed J-water contains to all appearance more S-water than at stat. 1383. JC-water occurs in more forms than at stat. 1383, owing to the fact that stat. 1369 lies nearer to the region of C-water than stat. 1383. On the other hand the MB-water forms are fewer, as the most saline of these have subsequently been mixed with B-water. During its west-going movement the M-water has been taken up in the underlying B-water.

It has to be noted, that the curve representing the JC-water in both diagrams for stat. 1383 and stat. 1369 lies somewhat under the line SC. This may come from cooling of the C-water when parts of it have been in contact with the atmosphere.

Stat. 1367: 33° 42′ N. 36° 16′ W. Observations to 2500 m.

At this station the influence of the M-water is to be noted up to about 800 m., but only up to 1500 m. do we find almost unmixed MB-water, and in this depth the M-water has increased the salinity only to $35.16\,^0/_{00}$. From 800 to 1500 m. we have mainly JB-water with a small admixture of M-water.

At a depth of 800 m. lies the oxygen minimum with the rather low value of $67.1\,^0/_0$. It is also low at a depth of 700 m., namely $67.3\,^0/_0$. The low oxygen contents are no doubt due to the influence of the S-water, and the S-water probably composes an important part of the J-water at 600—700 m. depth.

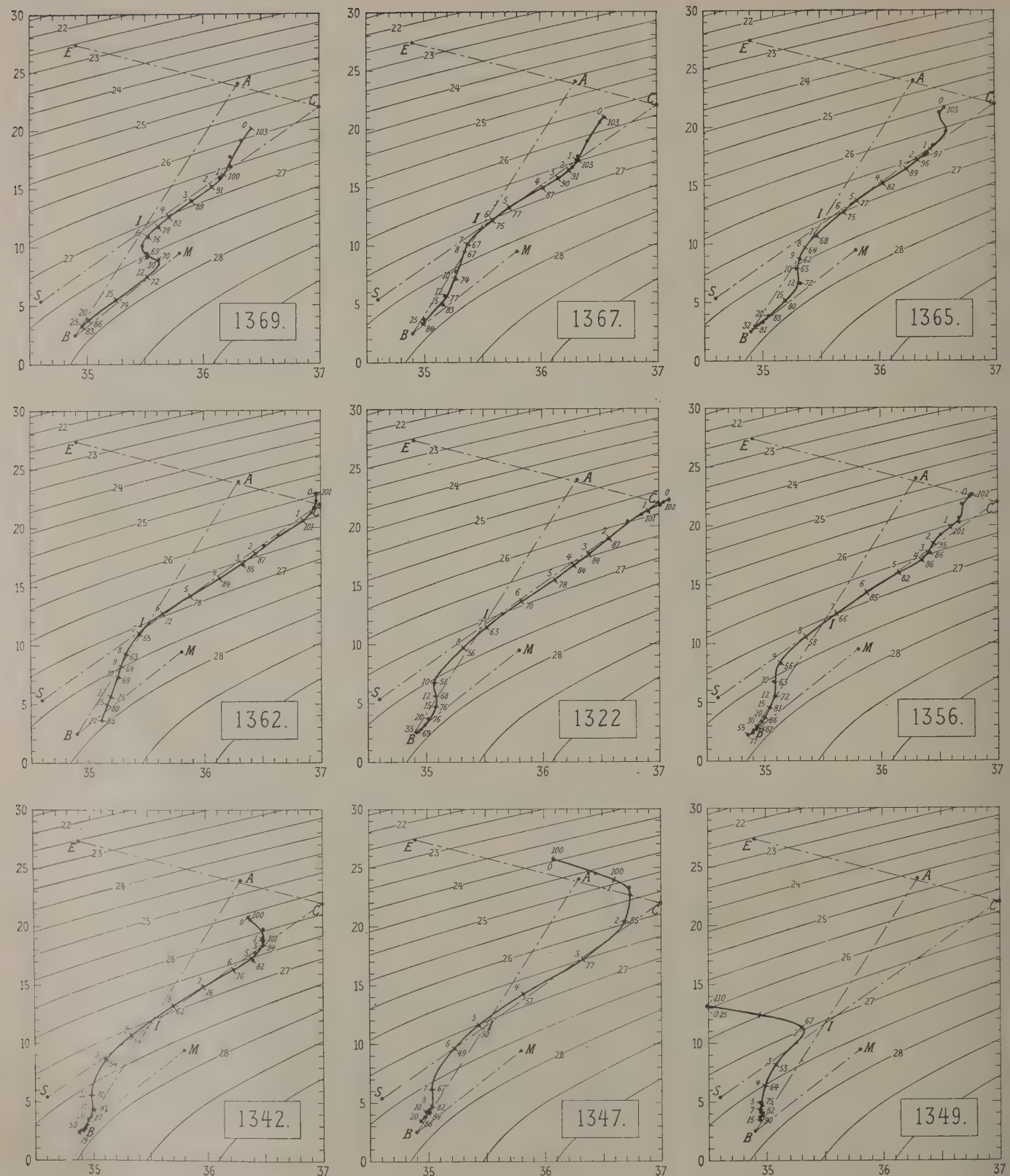


Fig. 17.

Between 100 and a little more than 600 m. we find water with temperatures and salinities lying on the CS-line, the oxygen diminishing from 103 % in 100 m. down to 75.2 % in 600 m. It may presumably be characterized as a mixture of JC-water with water formed by direct mixture of C- and S-water.

Stat. 1365: 31° 47′ N. 41° 41′ W. Observations down to 3200 m.

The influence of the M-water shows at this station up to about 1000 m. depth, that is scarcely as high as at stat. 1367. On the other hand, almost unmixed MB-water reaches to about 1200 m. The water in depths less than 1000 m. is of similar composition to that at stat. 1367.

Stat. 1362: 28° 57′ N. 47° 24′ W. Observations down to 2000 m.

Comparing the TS-curves for stat. 1362 and stat. 1367 we see that they nearly accompany one another for salinities less than 36.3 ‰. This salinity is found about 140 m. at stat. 1367, but not until

Table 13.

Salinity ‰	Stations	1383	1369	1367	1365	1362
35.5	Depth	450	630	640	680	660
	Temperature	11.0	10.7	11.5	11.2	11.6
	Oxygen	82	75	72	69	66
35.7	Depth	250	420	520	600	580
	Temperature	12.5	12.4	13.0	12.7	13.0
	Oxygen	93	82	77	74	72
35.9	Depth	100	300	450	460	500
	Temperature	13.6	14.0	14.2	14.2	14.3
	Oxygen	102	89	83	79	78

somewhat over 300 m. at stat. 1362. Contrary to stat. 1367 unmixed C-water occurs on the surface at stat. 1362.

At the Stat. 1383, 1369, 1367, 1365 and 1362 so far dealt with, it has been supposed, that the mixture represented by points on the line CS is partly JC-water, partly CS-water and that the J-water entering into the mixture at the various stations is of variable composition.

It may be of interest therefore to consider the schematic Table 13 where the depth, temperature and oxygen accompanying three salinities: 35.5 ‰, 35.7 ‰ and 35.9 ‰ are noted for the different stations.

We see that stat. 1383 occupies an exceptional position. The water-mixture indicated by the salinities occurs at this station at considerably smaller depths than at the others and we note specially that its oxygen contents are considerably higher than those of the other stations. The water-mixture at stat. 1383 consists of JC-water, whereof the J-water is mainly formed of AB-water and as surface-water (p. 34) but only contains CS-water in less degree.

For the last three stations the water-mixture may also be called JC-water, but the J-water chiefly consists of CS-water. Taking the oxygen of S-water at 40 % and of C-water at 98 % an approximate calculation would give for CS-water of the cited salinities the oxygen contents 62 %, 67 % and 72 %, and it has been noted that the oxygen of the CS-water in this region might be essentially lessened owing to exclusion from the atmosphere. Since the water-mixture nevertheless contains more oxygen than the approximate estimate, this may be due to the fact that the J-water contains AB-water and a surface-water mixture, besides the CS-water, or that aeration from the atmosphere has taken place (winter cooling).

Finally, the intermediate water-layer at about 200 m. west from the Bermudas, with a temperature of ca. 19° and a salinity of ca. 36.5 ‰, may also have had some influence in the region where the stations

lie. This water may be characterized as CS-water, but in contrast to the ordinary CS-water with a temperature of about 19° and salinity 36.5‰ it is almost saturated with oxygen. For ordinary CS-water of the named temperature and salinity we should expect ca. 85% oxygen, which is also the case in the lowermost part of the intermediate water-layer with somewhat lower temperature and salinity.

Stat. 1369 forms a transition between stat. 1383 and the last three stations, but stands nearest the last, as can be seen from Table 13.

Stat. 1322 27° 02′ N 53° 39′ W. Observations down to 3500 m.

In 3000—3500 m. nearly unmixed B-water has been found with relatively small oxygen contents, ca. 70%. Between 1500 and 3000 m. the B-water is also most prominent, but the course of the TS curve indicates that an admixture of M-water is still found so far to the west. Probably some A-water is also present in these depths. Between 700 and 1500 m. we find CS-water, AB-water and probably also a small amount of M-water. It is possible that the intermixed AB-water has been formed by mixture of the descending B-water with J-water, which mainly consists of AB-water. The oxygen minimum is 56% in 800 m. where practically only CS-water is found with ca. 29% C-water and about 71% S-water. For this mixture we should expect the approximate oxygen contents: $\frac{98 \times 29 + 40 \times 71}{100} = 57\%$, thus in good agreement with the value found. From the surface to 700 m. depth we find CS-water. Possibly the CS-water is somewhat mixed with JC-water.

Stat. 1356 29° 56′ N. 59° 33′ W. Observations down to 5500 m.

In the greatest depths from 4000 to 5500 m. the water may be characterized as unmixed B-water. From 2000 to 5500 m. the oxygen decreases slightly with the depth and it may be assumed that the reneval in depths about 2000 m. proceeds more quickly than is the case with the water nearer the bottom. The enormous water-layer from ca. 1200 m to the bottom consists, we may believe, of B-water with relatively little admixture of J-water or A-water.

The bending of the TS-curve for depths between 2000 and 4000 m. might seem to indicate a slight admixture of M-water. Between 850 and 1200 m. we find a mixture of CS-water and JB-water, the last presumably consisting of AB-water. From 300 m to 800 m we have CS-water possibly with some admixture of JC-water. From the surface to 300 m. depth the A-water shows its influence in an irregular manner. The oxygen minimum is found at 900 m. in the lowest, almost unmixed CS-water (56.5%). Calculating the oxygen contents in the same way as before from the amounts of C-water and S-water mixed together we get 53%.

Stat. 1342 34° 00′ N. 70° 01′ W. Observations down to 5000 m.

From 1500 to 5000 m. we find AB-water with B-water greatly predominating and for this station the admixture of M-water is disappearing. From 1000 to 1500 m. we find a mixture of CS- and AB-water. The oxygen minimum lies at 1000 m. depth (54%). Calculated as before we get 52%. From 150 m. to 1000 m. we find mainly CS-water and from the surface to 150 m. CS-water mixed with A-water. The approximation to homogeneity which the water shows between 100 and 400 m. is also found at other stations west from Bermudas and has already been referred to (p. 18).

Stat. 1347 35° 42′ N. 73° 44′ W. Observations down to 2000 m.

Between 800 and 2000 m. we have a mixture of A-water and B-water, so that this, as also the sections Fig. 10 and 11 indicate, reaches a considerably higher level than at the earlier mentioned stations. Between 600 and 800 m. we find a water-mixture of CS-water and AB-water and between 200 and 600 m. CS-water. From the surface to 200 m. we have a mixture which mainly consists of AC-water. Near the surface however some water of a lower salinity than that of the A-water is intermixed, and at a depth

of 200 m. some S-water. In the unmixed CS-water at 600 m. depth, where the S-water is greatest in quantity, an oxygen minimum of 49.4 % is found. The calculation of oxygen contents in round numbers from the rate of mixture gives 55 %. In the remaining CS-water at this station there is also less oxygen than the approximate calculation gives. For example, in 400 m. we find 57.4 %, but the calculation gives 70 %. Stat. 1347 is thus distinguished clearly in this manner with regard to the oxygen in the CS-water from the immediately preceding, for which the observed and calculated oxygen contents were almost the same. We have reason to believe therefore, that the CS-water which has come to the region where stat. 1347 lies, is relatively stagnating. To this may be added that JC-water containing AB-water and the oxygen-rich, nearly homogeneous CS-water, which was found in ca. 200 m. at stat. 1342, does not find its way to the neighbourhood of stat. 1347 and is therefore unable to compensate for the reduction in the quantity of oxygen which the CS-water has suffered. This compensation has possibly taken place at least at some of the stations earlier referred to.

The oxygen contents 88.1 % in the AB-water at 2000 m. is higher than at the earlier stations and as the B-water composes by far the predominant mass in this depth, we see that a more direct supply of B-water occurs here than at the earlier stations, and we are probably also nearer to the district where the B-water is formed.

Stat. 1349 36° 16′ N. 74° 43′ W. Observations down to 1500 m.

Between 800 and 1500 m. is found AB-water almost as at the previous station. The uppermost part of the curve has on the other hand an altogether different appearance from the stations so far referred to. This is due to the fact, that water of low salinity from the Newfoundland region tends in a southerly direction along the west coast of America and gradually mixes with CS-water; in this way arises a water-mixture from the surface down to about 200 m., the salinity increasing greatly with the depth. At no depth of this station do we find a mixture of C-water and S-water alone, though between 200 and 300 m. there may be but a slight admixture of other water. In this depth interval the S-water composes about three-quarters, the remainder being mainly C-water. In conformity with this the lowest oxygen contents are found at a depth of 300 m. (52.6 %). Between 300 and 800 m. we have, as at the previous station, a mixture of AB-water and CS-water.

We shall now deal in a similar way as before with the selected stations in section X and section XI (see Figs. 1, 13 and 14) together with particular stations lying between sect. I and the sections named. (Fig. 63). The selected stations are: 1142, 1156, 1159, 1162, 1166, 1173 and 1182, together with stations D. 14 and D. 19 from the German Antarctic Expedition.

The TS-diagrams for the stations are reproduced in Fig. 18.

Stat. 1142 33° 26′ N. 16° 59′ W. Observations down to 3800 m.

The TS-diagram for this station is like the diagram for station 1383 (Fig. 15).

From ca. 1200 m. down to 3800 m. we find MB-water, but the mixture of the two sorts of water is more advanced than at stat. 1383. The highest salinity in the MB-water is ca. 0.2 ‰ lower at stat. 1142 than at stat. 1383 and occurs ca. 200 m. deeper. The M-water has sunk down under the mixture, analogous with what we found at the stations near the Azores.

This condition shows that the M-water has spread much less to the south than towards the north. In a depth of 3800 m. we find unmixed B-water with low oxygen contents (43.3 %), which shows that the B-water has been long on the way before reaching the region where stat. 1142 is situated and is probably stagnating. On the other hand, we find a maximum of oxygen at 2000 m. depth, presumably due to the quicker renewal of the B-element in the MB-water, which is therefore richer in oxygen.

Between 100 and 500 m. we find mainly CS-water possibly somewhat mixed with JC-water, which

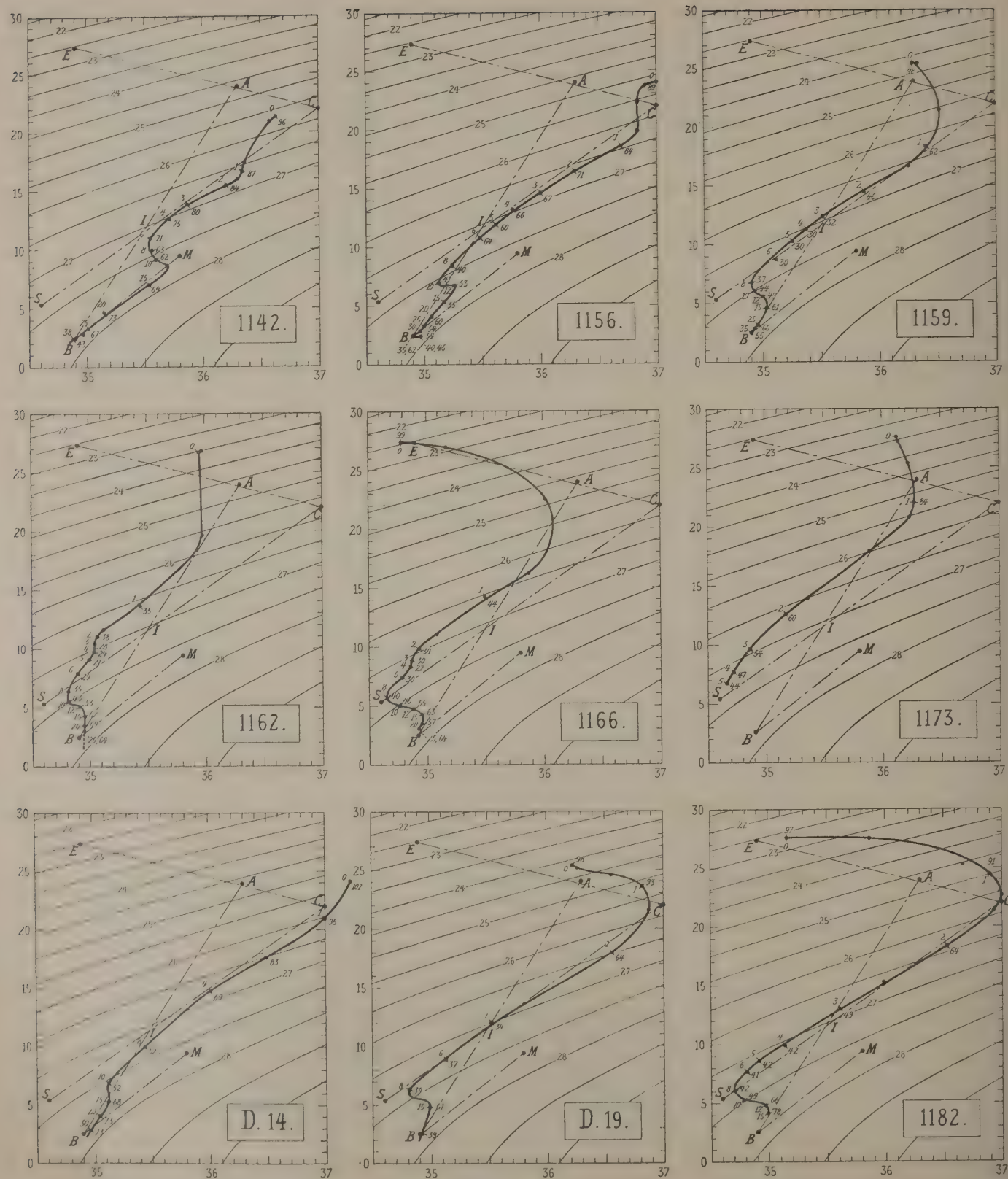


Fig. 18.

in that case also mainly consists of CS-water. This appears from the oxygen contents in the depths mentioned, which are only ca. 5% higher than the oxygen contents calculated roughly on the assumption that the water-mixture consists only of C-water and S-water. In this regard there is a characteristic difference between stat. 1142 and stat. 1383.

Between 500 and 1200 m. we find at stat. 1142 a mixture of CS-water and MB-water. The oxygen minimum is found in 1000 m. depth (61.6%).

Stat. 1156 25° 11′ N. 20° 57′ W. Observations down to 4000 m.

From ca. 1200 m. to 4000 m. the water is mainly MB-water, though mixed with some S-water. The maximum salinity of the MB-water is but small (ca. 35.3‰) compared with the last station. This shows that the M-water during its further extension towards the south has mainly sunk down to greater depths than at stat. 1142 and has been mixed with B-water in higher degree.

Between 75 and ca. 600 m. we find CS-water the oxygen contents of which, especially about 200 m., are lower than we should expect from the oxygen contents of the components, so that we may consider the water to be but slowly renewed.

Between 600 and ca. 1200 m. lies a mixture of CS-water and MB-water, the water between 600 and ca. 1000 m., only containing a small amount of MB-water. The oxygen minimum (ca. 40%) is at 800—1000 m. where the S-water composes the greatest proportion of the water-mixture.

With reference to the divergences between the TS-curve and the CS-line for depths down to 200 m., it may be remarked that from the surface down to 75 m. the difference is undoubtedly due to heating from the atmosphere and direct radiation of the sun. The observations at the station were made on 25, October. On the other hand, the peculiarity that the TS-curve for ca. 100 m. depth lies lower than the CS-line, may be explained by the possibility that a part of the water there comes from the ascending deep-water at the African coast.

Stat. 1159 17° 55′ N. 24° 35′ W. Observations down to 3500 m.

This station lies directly north of the Cape Verde Islands and we see that the influence of M-water is scarcely noticeable here. The addition to the B-water in 2500 and 3500 m. may possibly be M-water, but perhaps also AB-water (or JB-water). As at the last mentioned stations the oxygen contents in the unmixed B-water are less than in the water-mixture lying above this.

Between 100 and 800 m. we find CS-water of highly varying temperatures and salinities from $T = 18.2°$, $S = 36.4‰$ to $T = 6.7°$, $S = 34.9‰$ and with abnormally low oxygen contents, down to 29.5% at a depth of 500—600 m. We may therefore suppose that this water-mixture is but very slowly renewed.

Comparison with stat. 1156 and 1142 shows that water of the same temperature and salinity occurs at much smaller depths at stat. 1159 than at those stations. For example, we find the salinity of 35.5‰ at stat. 1159 in 300 m. and at stat. 1156 first at 600 m. depth. We may therefore conclude that an ascending movement of this water-mixture has taken place in the region of the Cape Verde Isles, and that the slow renewal referred to is connected with this movement.

In section X Fig. 13 the ascending movement at stat. 1159 shows itself in the course of the isotherms and isohalines. We may presume that the ascending water-movement near the Cape Verde Isles continues in the known ascending water movement north of these islands on the coast of Africa. The fact that the TS-curve of stat. 1159 for depths from 100 to 800 m. departs somewhat from the line CS, is possibly due to an infusion of water from an intermediate layer in about 300 m. depth from a region south of the Equator. The influence of this water-layer on the regions north of the Equator will be referred to later. (p. 42).

Between 800 and 2500 m. at stat. 1159 we find a mixture of CS-water and B-water with a slight admixture of A-water (or J-water) and possibly M-water. From the surface to 100 m. an admixture of water with lower salinity is apparent (Equatorial Current).

Stat. 1162 13° 35′ N. 30° 11′ W. Observations down to 2500 m.
Stat. 1166 10° 16′ N. 40° 41′ W. — — - 2500 m.
Stat. 1173 6° 18′ N. 48° 58′ W. — — - 500 m.

These stations lie in Section XI on a line from the Cape Verde Isles to Guayana. In 2500 m. depth at stat. 1162 and 1166 we find B-water with the known characters. At station 1173 the observations were only taken down to 500 m. At stat. 1162 and 1166 the TS-curve for depths between ca. 1500 and 2500 m. has a course which shows that the water here cannot be a mixture of B-water and S-water only; water of a higher salinity is also mixed with it. The influence of the M-water is probably disappearing in this region and we may assume that the B-water on sinking down from the surface in northerly regions has been assimilated with A-water or possibly J-water.

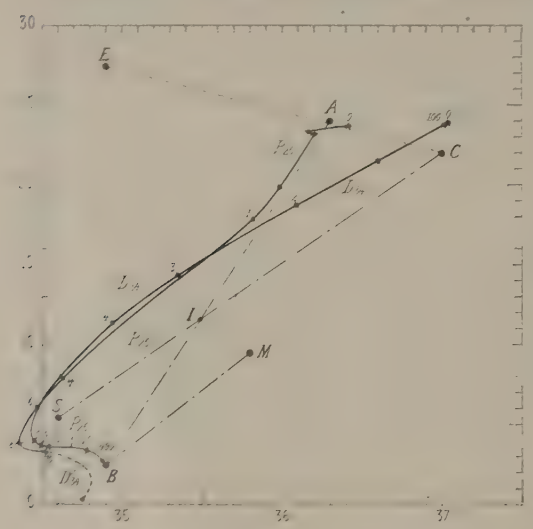


Fig. 19

In agreement with the definition of S-water, we find this almost unmixed at a depths of 800—900 m. at stat. 1166, whereas at stat. 1162, which is more to the north, it is mixed with the upper and underlying layers.

Between 400 and 800 m. the TS-curve takes a course which indicates that the water mainly consists of CS-water, mixed however in no little degree with a water-mixture which at stat. 1162 is found between 50 and 200 m., and for stat. 1166 and stat. 1173 respectively between 75 and 250 m. and between 100 and ca. 300 m., thus deepest on the whole in the south-western part of section XI.

This water-mixture, which has not been found in the northern part of the region referred to, has a similar character to the CS-water and comes certainly from the mixing regions found at the boundaries of the region at ca. 20° S. Lat. with the high salinity at the surface, ca. 37 ‰.

At the boundaries of this region we have similar conditions for mixing between the water of high salinity occurring near the surface and the intermediate layer at about 800 m. depth, which comes from the south. The intermediate layer at about 800 m. in the region about 5° N. Lat. is the S-water, but at the more southern latitudes, this intermediate water-layer shows a lower temperature and a lower salinity and by mixing with the water of high salinity near the surface the TS-curve for the water-mixture obtains a position which is nearly the same as that for the stat. 1162, 1166 and 1173 for depths between 100 and 200 m.

That this explanation of the origin of the water-mixture mentioned is correct, is confirmed by the situation of the TS curves for D 34 from the German Antarctic Expedition 1911—12, and for P 25 by the German "Planet" Expedition 1906—07, and moreover by several of the stations lying in this region taken by those expeditions. The two stations D 34 and P 25 are situated at 18° 17′ S. 34° 9′ W. and 16° 37′ S. 4° 40′ W. The TS curves of these stations are given in Fig. 19 with line CS etc. shown.

The characteristic bending of the TS curves at stat. 1162 and 1166 for depths between ca. 200 and ca. 400 m. may therefore be explained in this way, that a mixture of CS-water and water analogous with it from about 20° S. Lat. is found in the depths mentioned. At stat. 1173 the TS curve shows a

somewhat different course, presumably because not much CS-water occurs at this station. As to the uppermost layers, we find there a mixture between the just-mentioned mixture coming from the south and E-water, and the influence of the atmosphere is also in evidence.

The distribution of the oxygen at stat. 1162 and 1166 shows the characteristic condition, that the oxygen minimum lies in the uppermost part of the CS layer and goes down to 21.0 % and 21.7 % respectively. These oxygen contents are much lower than those of the S-water, and the CS-water mentioned may be considered to have been isolated for a longer time from the atmosphere than the S-water. It has probably come to the localities represented by stat. 1162 and 1166 from the area of the Cape Verde Isles (see isobar chart. Fig. 53). As mentioned p. 41 the movement of the S-water at the Cape Verde Isles is but slow, but owing to the ascending movements there it is gradually carried over into the current system, as can be seen from the situation of the isobars. The water-mixture coming from the south which has been found from ca. 200 down to ca. 400 m. at stat. 1162 and 1164, has probably also had an ascending movement along with a slow horizontal movement. The oxygen contents in the mixture south from the Equator are considerably greater than at stat. 1162 and 1166.

Stat. D 14. 24° 57′,5 N. 33° 35′ W. Observations down to 5680 m.
Stat. D 19. 17° 22′ N. 45° 10′ W. — - - - 3920 m.
Stat. 1182. 13° 03′ N. 59° 50′ W. — - - 1500 m.

These three stations lie in a line approximately parallel to the southern section just referred to.

Stat. D. 14. At this station nearly unmixed bottom-water is found at 3000 m. and at the bottom at 5680 m. depth, where only the salinity was determined, it was found to be 34.88 ‰. Between 2000 and 3000 m. we find mainly B-water but with a slight mixture of A-water (J-water) and possibly some M-water. Between 100 and 800 m. the water in the main may be characterized as CS-water, though the TS-curve lies a little lower than the line CS. Between 800 and 1500 m. the TS curve follows fairly well the line AB, but this may partly be due to the circumstance that the water-masses present of CS-water and MB-water are so mixed, that the TS curve has received the position indicated.

As far north as at this station (ca. 25° N. Lat.) we find the S-water greatly mixed with the water above and below. The smallest values of oxygen (ca. 52 %) are found at 800 m. and 1000 m. depth, where the S-water may be considered to be most prominent, but from mixing with the upper and underlying water the oxygen contents of the mixture are greater than the original (40 %). The oxygen in the upper and lower layers shows the usual picture.

Stat. D. 19. In a depth of 3920 m. we find unmixed B-water, and between ca. 2000 and 3920 m. presumably B-water somewhat combined with A-water (J-water). In 800 m. depth there is nearly unmixed S-water and between 800 and 2000 m. a mixture of S-water and the underlying mixed B-water. Between 150 and 800 m. we find greatly varying kinds of CS-water, the TS curve for a long distance almost following the line CS. At a depth of 400 m. there is possibly a small mixture of the earlier mentioned water from regions south of the Equator (p. 42).

For the uppermost layers from the surface down to 150 m., the TS curve shows a course which is due partly at any rate to the influence of E-water. Small oxygen contents are found at depths of 400—800 m. This may be due partly to the small oxygen contents of the S-water, partly to the fact that the mixture in these depths comes to some extent from the region of the Cape Verde Isles where the oxygen contents are low. Possibly the water-mixture coming from the south of the Equator plays some part in this low proportion of oxygen. In greater depths the influence of the relatively large amount of oxygen in the B-water is appreciable.

Stat. 1182. At a depth of 1500 m. we find B-water with a slight mixture of A-water (J-water). At 800 m. there is almost unmixed S-water, and between 800 and 1500 m. a mixture of CS-water and AB-water (JB-water). From 125—800 m. we find CS-water of very different composition, but as the TS-curve for depths between 250 and 800 m. lies somewhat higher than the line CS, we may suppose that some addition of the water mentioned (p. 42) from the region south of the Equator has taken place.

The oxygen contents are low (40—42 %) at depths of 400—800 m. as at the previous station, for the same reasons as there, but perhaps the mixture from the south has greater influence at this station.

From the surface to ca. 100 m. we find EC-water and at the surface itself nearly unmixed E-water.

In the same way as before we shall now consider the TS diagrams drawn on Fig. 20 for the stat. 1261, 1241 and 1239 north of the Antilles, the two stat. 1268 and 1214 in the Caribbean Sea, as well as stat. 1227 in the Gulf of Mexico, north from the west end of Cuba.

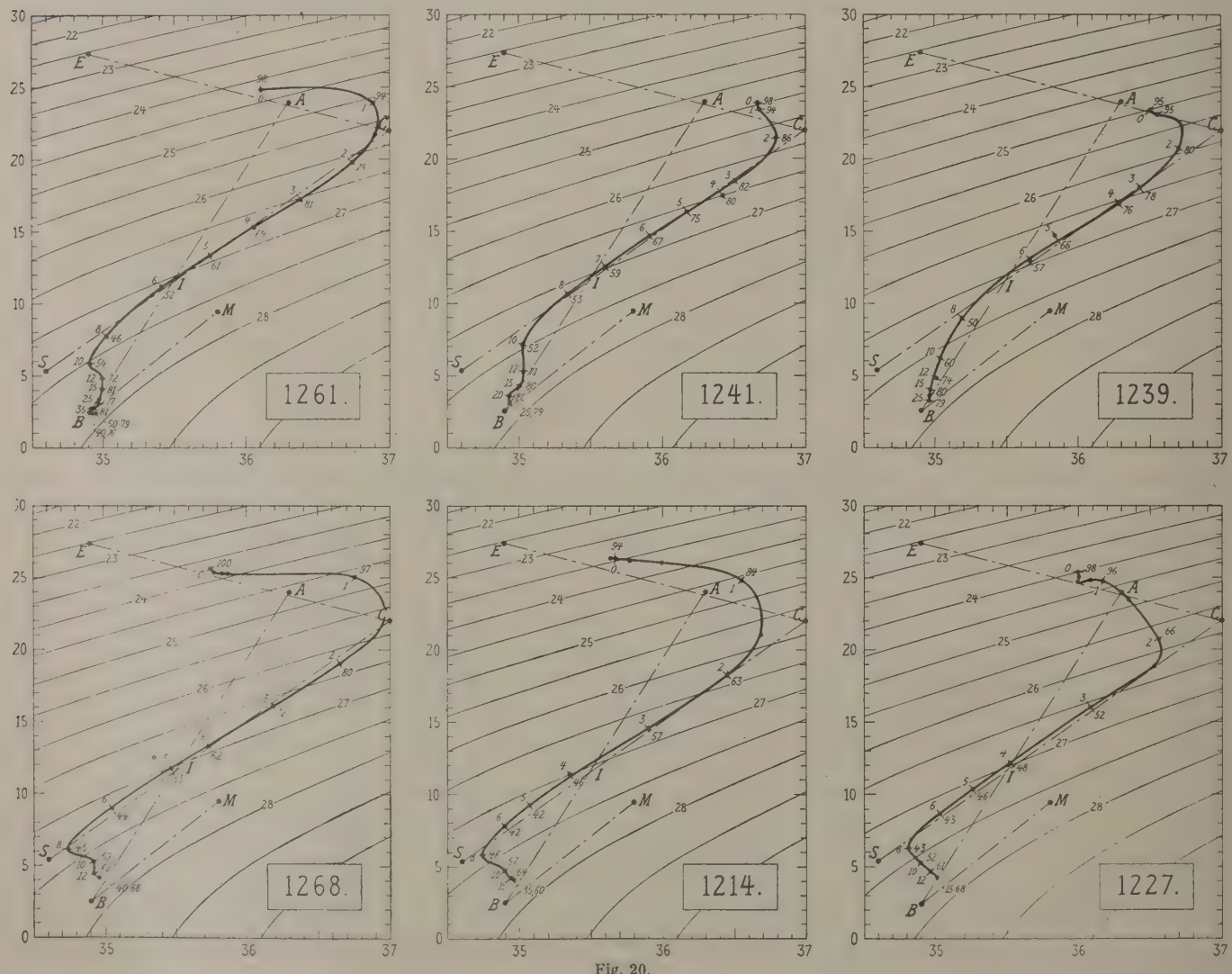


Fig. 20.

At first we shall consider the three stations outside the islands:

Stat. 1261. 19°04′ N. 65°43′ W. Observations down to 5000 m.
Stat. 1241. 25°18′ N. 74°00′ W. — — - 2500 m.
Stat. 1239. 25°50′ N. 76°55′ W. — — - 2500 m.

Of the three stations mentioned, two, stat. 1261 and 1241, lie in the earlier mentioned section II (Fig. 3).

As will be seen from the TS curves, the water at the 3 stations is of the same kind. Especially characteristic is the prominence of the B-water in greater depths. With but little admixture of A-water (or J-water) it reaches at these stations up to the relatively small depths of 1200—1500 m.

For the sake of comparison we may note, that the little mixed B-water at the American coast off Norfolk (stat. 1347 and 1349) reaches up to even less depths, and that in the Sargasso Sea (stat. 1356 and 1342) it lies somewhat deeper than at the Antilles.

That the renewal of the but little mixed B-water in these regions takes place relatively quickly is shown by the oxygen contents occurring here. At the above-named three Antilles stations the mean values of temperature, salinity and oxygen at 2000 m. depth are 3.51°, 34.96‰ and 81% respectively. Water of approximately the same temperature and salinity is found at the stations 1356 and 1342 at 2250 m depth with oxygen contents of ca. 85%, and water likewise with nearly the same temperature and salinity at the stations 1347 and 1349 in depths of 2000 m. and 1500 m. respectively, with the oxygen contents of 88.1% and 89.5%.

It may be concluded from this that the renewal of the water at 2000 m. depth and more, at the northern side of the Antilles, chiefly occurs by the agency of the deep current along the American coast and that its oxygen contents are reduced from about 89% to ca. 81% during this movement.

Between ca. 800 m. and 1500 m. we find a mixture of AB-water (JB-water) and CS-water, in which the B-water and S-water form the main components. The TS curve at the three stations is of a different appearance for this intermediate layer, due to the more or less dominating influence of the S-water.

At stat. 1261 the S-water is most prominent, but least at stat. 1239, where the TS curve approaches the line AB in the diagram. The advance of the S-water on the north side of the Antilles can be clearly seen in section II, Fig. 3.

At all three stations we find distinct CS-water between about 200 and 800 m. with somewhat lower oxygen contents than might be expected according to the mixing conditions.

The oxygen minimum (ca. 50%) is found at ca. 800 m., thus in the lowest part of the water-mixture which alone contains C-water and S-water, but on account of the fairly considerable admixture of C-water in the S-water, it is not so marked as further to the south. An approximate calculation of the oxygen contents at 800 m. based on the oxygen of the C- and S-water gives ca. 60%.

The surface-water down to about 200 m. chiefly contains C-water mixed with E-water. The mixing however has been of such a nature that salinities near to the salinity of the unmixed E-water do not occur. The E-water itself is much more apparent at the surface east from the Caribbean Islands (stat. 1182 and 1185).

The stations inside the islands are:.

Stat. 1268. 17°13′ N. 64°58′ W. Observations down to 4000 m.
Stat. 1214. 14°21′ N. 76°50′ W. — — - 3500 m.
Stat. 1227. 23°40′ N. 82°31′ W. — — - 1500 m.

Of these stations 1268 and 1214 lie in the Caribbean Sea and 1227 in the Mexican Gulf north from the western end of Cuba.

The stations in the Caribbean Sea were investigated down to considerable depths, resp. 4000 and 3500 m., but nevertheless we do not find in the deep water such low temperatures as outside. The reason is doubtless, that water from greater depths than 1800 to 2000 m. cannot penetrate from the Atlantic over the thresholds which exist between the islands bordering the Caribbean Sea. The water from ca. 2000 m. to the bottom of this sea can well be designated a water-mixture of A-water (or J-water) and B-water from the Atlantic, but it only occurs with the definite composition it has on passing over the thresholds.

When this water manages to get into the Caribbean sea and sinks down to the bottom, it may certainly stay there a relatively long time before it is led away again on mixing with the upper layers. The low oxygen contents in the deep water at stat. 1214 and at stat. 1268 at the Anegada Passage resp. ca. 60 % and ca. 67 %, also indicate this, whilst outside the Anegada Passage at stat. 1261 we found 82 % at 2000 m. depth.

Even if the oxygen contents are considerably lower in the Caribbean Sea than outside, they are not so low that we can call the water stagnant. This is due to the specific gravity of the water, reduced to the same pressure, being nearly the same at all depths below ca. 2000 m. The increase shown by the temperature with the depth is no doubt due to the adiabatic compression of the water. The difference in temperature between 3000 and 4000 m. is 0.12° at stat. 1268, and between 2500 m. and 3500 m. 0.09° at stat. 1214, whilst the calculated rise of temperature due to the adiabatic compression should amount to 0.13° and 0.12° respectively W. Ekman (1914). The agreement is however not everywhere so good.

Between 800 and 1500—2000 m. we find a mixture of the AB-water (JB-water) which passes over the threshold, and S-water mixed with C-water. It is characteristic that the S-water is so predominant in the Caribbean Sea, much more so than at stat. 1261, north of the Anegada Passage, not to speak of the more western stations outside the islands, stat. 1241 and 1239.

On the other hand, the TS curves for the stations in the Caribbean Sea for depths of 800 to 1500—2000 m. are almost congruent with the TS-curve for the same depths at stat. 1182 (see Fig. 18). It appears from this that the water east of the Caribbean Islands finds its way into the Caribbean Sea.

The inflow and renewal in depths about 800 m. are certainly rapid, the oxygen contents in these depths being essentially the same outside and inside the Islands. On the other hand, the difference in the oxygen contents at about 1500 m. outside and inside the islands is almost as in the deeper layer. The inflow in ca. 1500 m. probably takes place mainly through passages in the row of the Great Antilles.

The TS curve for stat. 1227 in the Mexican Gulf also shows for depths 800—1500 m. great resemblance to the TS curve for the two stations in the Caribbean Sea, which together with uniformity of the oxygen contents is explained by the rapid transit of the water.

Of special interest is a comparison between the TS curves for depths of 250—800 m. at the stations referred to in the Caribbean Sea and in the Gulf of Mexico, as well as stat. 1182 outside the Caribbean Islands. In the main the curves follow the line CS, but it holds good for all the stations that the curves for mean depths in the water-layer mentioned lie somewhat higher than the CS line.

This is most prominent at Stat. 1182 (Fig. 18) outside the islands and is undoubtedly due to an infusion of the water-mixture coming from the south, which has been formed analogous to CS-water, and has been referred to earlier (p. 42). On entering the Caribbean Sea this water-mixture makes its influence felt at the stations mentioned, and in higher degree at stat. 1214 than at stat. 1268, which lies more to the north near the Anegada Passage.

The relatively low amount of oxygen found at the stations mentioned at depths of about 250—800 m. is explicable at least in part from the water-mixture coming from the south.

In the uppermost layers from the surface down to 100—200 m. depth we find EC-water at the stations mentioned in the Caribbean Sea and the Gulf of Mexico. This water-mixture appears most uniform at stat. 1227, where it has come nearly to compose what has been defined as A-water.

In the foregoing, with help of chosen stations mainly from the »Dana« Expedition, an outline

sketch has been given of the places and depths where the different sorts of water and their mixtures occur. As mentioned p. 34 however, there is some uncertainty with regard to the kinds of water-mixtures which occur at the northern boundary of the region of the Atlantic here considered, and it may therefore be of interest to undertake an analysis also of the available hydrographical material from the region north of that already dealt with.

Of such material a good deal has been published and for the purpose of a comparative survey similar to the foregoing observations from the stations noted on the chart, Fig. 63: C 44, MS 65, M $^{22}/_{7}$, Th 60, HN 60 and 1387 are selected.

The position of the stations is as follows:

C 44	41° 19′ N.	63° 59′ W.	Observations	taken	22. VII. 1915.
MS 65	37° 12′ N.	48° 30′ W.	—	—	25. VI. 1910.
M 22/7	55° 07′ N.	24° 19′ W.	—	—	22. VII. 1913.
Th 60	56° 00′ N.	9° 57′ W.	—	—	11. VI. 1905.
HN 60	49° 33′ N.	18° 59′ W.	—	—	12. VII. 1914.
1387	46° 28′ N.	8° 01′ W.	—	—	25. VI. 1922.

The observations have been made by different expeditions, namely: The Canadian Fisheries Expedition 1914—15, led by J. Hjort, (C. 44) (Paul Bjerkan 1918), John Murray and Johan Hjort's Expedition with the "Michael Sars" 1910 (M S 65) (B. Helland-Hansen 1912), the expeditions sent out by the Danish "Kommissionen for Havundersøgelser" with the "Margrethe" 1913 (J. P. Jacobsen 1916) and with the. "Thor" 1905 (J. N. Nielsen 1907) (M 22/7 and Th 60), the expedition conducted by Helland-Hansen with the "Armauer Hansen" 1914 (HN 60) (B. Helland-Hansen and Fridtjof Nansen 1926) and stat. 1387 from the "Dana" Expedition 1921—22.

The TS diagrams of the stations are reproduced in Fig. 21.

Stat. C 44 lies outside the shelf south of Nova Scotia, but the observations were only taken down to 400 m. depth. There can be no doubt however, that the continuation of the TS curve, as indicated by the dotted line in the diagram, tends towards the point B. Thus, generally speaking, the TS curve for depths from 75 m. downwards follows the line AB, but the deviations are so great that one cannot characterize the water in greater depths than 75 m. as only AB-water. At depths between 200 and 400 m. the CS-water makes its influence felt and there is possibly also a considerable admixture of CS-water in the depths less than 200 m.

The mixture represented by the point I is of special interest. As mentioned p. 34 it may be of different origins, but for stat. C 44, here referred to, we may certainly assume that the J-water mainly consists of AB-water. Presumably the region where stat. C 44 is situated is more particularly the place of formation of the J-water consisting of AB-water, since — as earlier mentioned — (p. 34) a mixture of A-water and B-water of higher temperature than that of the J-water is rapidly mixed with water of low salinity from the region of the Banks. The part of the curve for the depths 0—50 m. represents such a water-mixture.

Stat. MS 65 is situated at the boundary between the region of the Gulf Stream at Newfoundland and the Sargasso Sea and in agreement with this the TS diagram shows the CS-water at 100—800 m. depth which is characteristic of the Sargasso Sea. The TS curve however lies somewhat higher than the CS-line, possibly due to some mixture with AB-water. From the surface down to 100 m. the course of the curve may be explained by an admixture of A-water to the uppermost part of the CS-water, which is probably to some extent the case, but a heating of the uppermost CS-water from the atmosphere can also explain the course of the curve. Between 1000 and 2000 m. we find JB-water, and between 800 and 1000 m. a mixture of JB-water and CS-water.

Stat. M 22/7 is situated so far to the north (ca. 55° N. Lat.) that the CS-water can scarcely have any influence. The TS curve, Fig. 21, shows also that the water between 100 to 2000 m. may be regarded as almost exclusively AB-water. The observations appear to be somewhat uncertain, and besides were made under somewhat primitive conditions. It is not out of the question, however, that the salinity of the A-water and B-water may vary somewhat. Whilst the water at 2000 m. depth is very rich in oxygen (84.4%), the water at 1000 m. has the oxygen minimum (69.8%). The renewal of the water in great depths may therefore be considered to proceed rapidly in this region also, whereas at 1000 m. depth the renewal of the intermediate layer proceeds but slowly.

Stat. Th 60 lies north-west of Ireland at 56° N. Lat. Observations were taken down to 1900 m. depth. The TS curve for depths between 100 and 1900 m. mainly follows the line AB, but shows a bend over to the line MB. We may therefore conclude, that AB-water occurs in this region in the mixing conditions represented by the line BJ, combined with some M-water. The water occurring at 1100 m. may

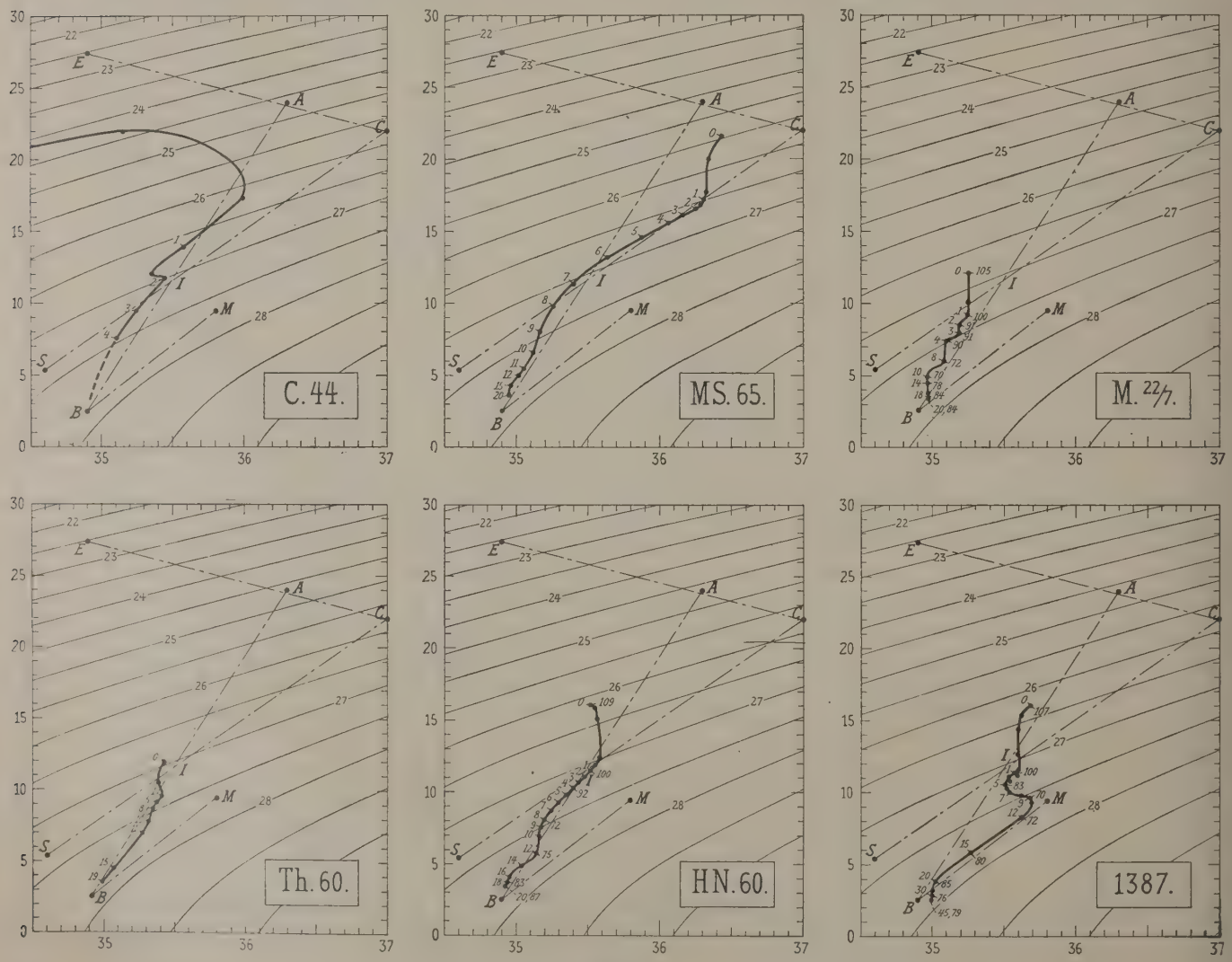


Fig. 21.

have arisen from the mixing, in round numbers, of 60 % B-water, 25 % M-water and 15 % A-water. The occurrence of Mediterranean water in these regions has been proved earlier by J. N. Nielsen (1907).

Stat. H N 60 lies south west of Ireland, about 300 miles from the shelf. Observations were made down to 2000 m. Excluding the observations for the uppermost 50 m. the whole of the TS curve with a somewhat bent course mainly follows the line JB. At depths from 50 down to 700—800 m. however, the curve nearly bisects the angle between the lines JS and JB, and we may suppose therefore that a water-mixture of AB-water and CS-water occurs at these depths. At 100 m. we have J water, represented by the point J. According to the position of stat. H N 60 we may expect to find J-water composed of all the forms already mentioned: surface water-mixture, AB-water and CS-water. Owing to the high oxygen contents however, (100.5 % at 100 m., 92 % at 400 m.), the CS-water is apparently but little represented. At 800 m. we find the oxygen minimum (72.3 %) and the S-water makes its influence felt.

The bend in the curve at 1200 m. is certainly due to the influence of the M-water. At this depth the oxygen amounts to 74.8 % and is thus higher than the amount for the M-water, even higher than the oxygen contents in the overlying water. This is due to the influence of the B-water. At 2000 m. depth the oxygen contents amount to 87.1 %.

Stat. 1387 is situated in the Bay of Biscay outside the shelf at 4650 m. depth. The TS curve shows that the water from 1200 m. down to the greatest depths is distinctly MB-water. At 2000 m. where the amount of B-water is relatively great, we have an oxygen maximum (84.7 %). At this depth the renewal of the water probably takes place most rapidly.

Between 100 and 600 m. we have water which is almost uniform in regard to temperature and salinity and which consists for the most part of J-water, composed of all the three forms of this already mentioned p. 34. At 100 m. depth the amount of oxygen is 99.7 % and at 600 m. 81.3 %. It may be assumed therefore that the lowest part of the J-water contains especially CS-water, whilst the uppermost part mainly consists of a surface-mixture and AB-water.

Between 600 m. and 1200 m. we find a mixture of J- and MB-water, and at 900 m. the oxygen contents characteristic for M-water (69.8 %), which is the lowest at this station.

From the surface down to 100 m. depth the salinity is about the same as in the J-water lying below, but the temperature is considerably higher at the surface (16.02°) than in the J-water. It may be concluded that this water comes from the region west of the British Isles and that it has there been identical with the J-water, but during its movement southward has been warmed up by the heat of summer.

4. SUBDIVISION OF THE ATLANTIC REGION BETWEEN THE EQUATOR AND CA. 60° N. LAT. INTO SMALLER AREAS (I—XXIV) AND THE DESCRIPTION OF THESE AREAS WITH THE AID OF T-S DIAGRAMS

In the previous chapter an account has been given of the principal kinds of water-masses occurring in the part of the Atlantic considered, as also of their geographical distribution. In the present chapter an endeavour will be made to divide the whole region into areas in such a manner that each of these areas will contain approximately uniform hydrographical conditions, at least in certain regards, distinguishing them from the other areas.

It will readily be understood, that such an investigation must be in some measure in the nature of a sketch, as we cannot hope to obtain all possible information from the available material. Further, the subdivision adopted here was already made at such an early period in the working out of the present

results that a slight change here or there might have been desirable on several points. The reason for not doing so was simply, that the problematic gain did not appear sufficiently great by comparison with the labour necessary in making such a change.

The subdivision used can be seen from the chart, Fig. 63, where the boundaries are indicated for the areas marked I—XXIV. Summaries of the hydrographical conditions in each one of the areas are given partly in graphic form (Figs. 22—52), partly in tables which show as a rule the average values of the

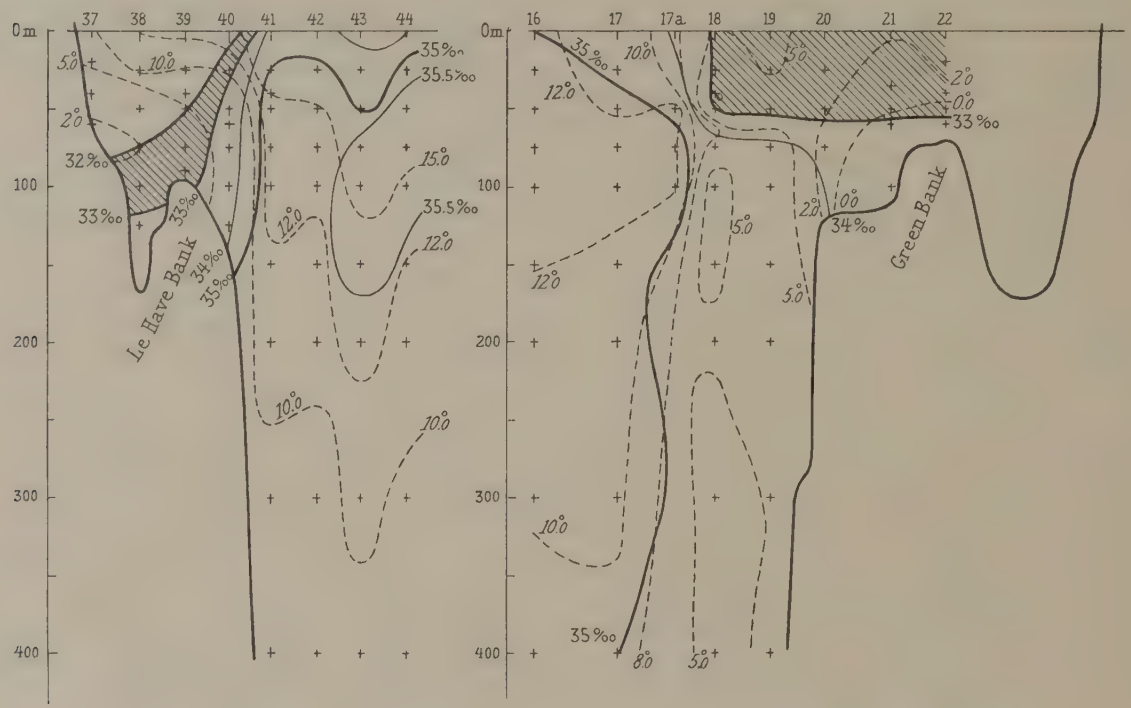


Fig. 22. Sections at Nova Scotia and at the Great Bank of Newfoundland reproduced after Paul Bjerkan

temperature, salinity and oxygen contents at the different depths within each area. Further information will be given in the following treatment of the single areas.

Area I, as can be seen from the chart, Fig. 63, is bounded by the east coast of North America as far as Cape Hatteras, from there by a line out to the position 40° N., 60° W., then along the 40° of latitude as far as 50° W., continued by a line from 40° N., 50° W. to a position ca. 45° N., 30° W., and lastly towards the east by a curved boundary line from the last position tending mainly in a northerly direction between 24° W. and 31° W. In the north the boundary line may be placed at ca. 60° N. Lat.

As will be seen, Area I lies outside the region investigated by the "Dana", but it must naturally be taken account of in considering the influence its water has upon the remaining portions of the North Atlantic. Owing to the great differences within the Area as regards the hydrographical conditions, some parts may be dealt with separately.

In the south-western and western part of the Area the principal movement of the water from Cape Hatteras to the Newfoundland banks forms a continuation of the Florida and Antilles Currents. The water-masses of the uppermost layers down to ca. 100 metres, which are carried northwards parallel to the American coast to the region, off Cape Hatteras, have essentially the same salinity and temperature

as the water in the Florida and Antilles Currents. They represent the A-water defined in previous pages ($T = 24°$, $S = 36.3\ ‰$ and $O_2 = 96\ \%$).

On its passage to the Newfoundland banks this water meets with the Labrador Current which brings down water with a low salinity and icebergs from the northern latitudes and the icebergs on melting over the banks reduce further the salinity of the water. Again, the Gulf of St. Lawrence sends great masses

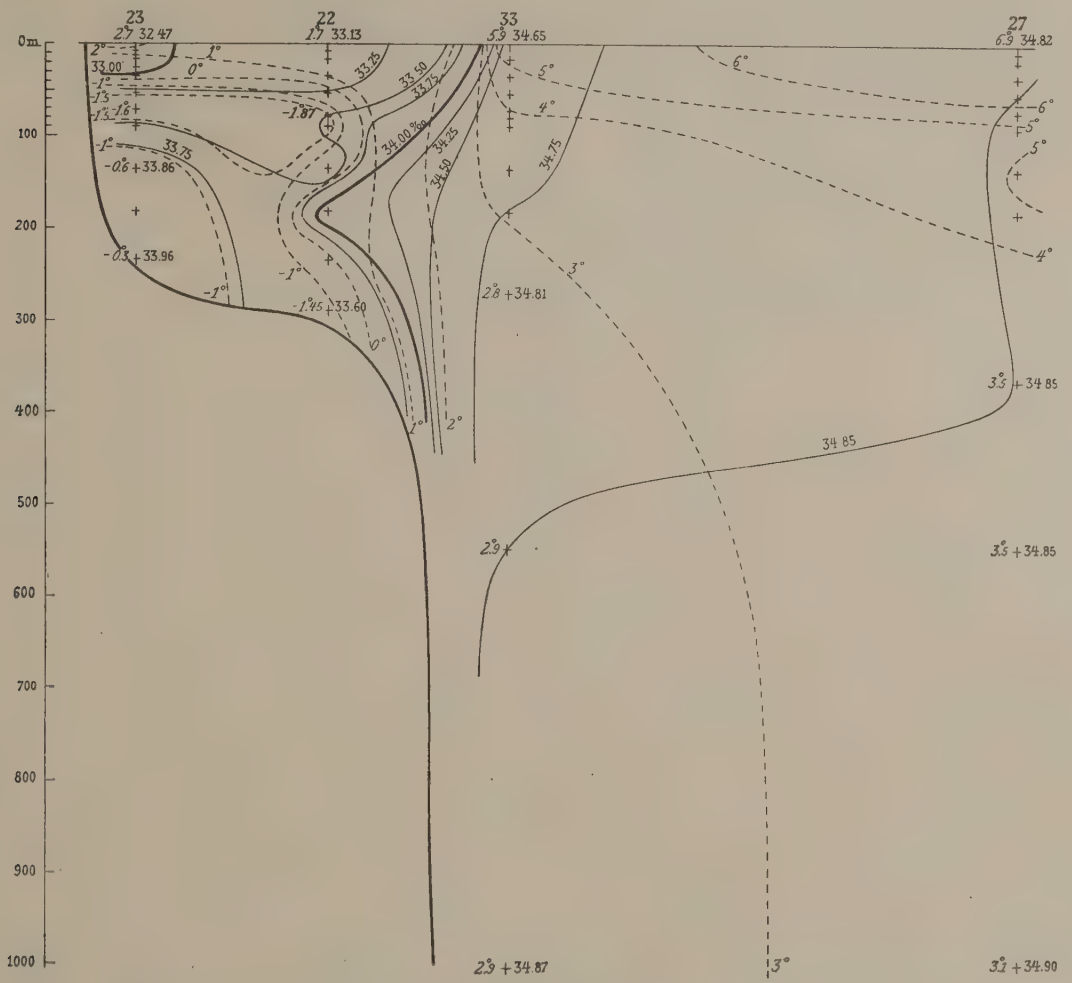


Fig. 23 a. Section north of the Great Bank of Newfoundland reproduced after D. Matthews.

of water likewise of low salinity through the Cabot Straits into the region of the Newfoundland banks. What part relative to each other is played by these water-masses of low salinity in the hydrographical conditions, can hardly be determined at present. That each is of importance, has been shown by the investigations carried out by Paul Bjerkan (1918) and J. W. Sandström (1918) on the basis of the hydrographical material collected in 1914—15 by J. Hjort's expedition in the Canadian Atlantic waters and the reports made by the International Ice Patrol.

Fig. 22 reproduces the sections farthest to the west and east given by P. Bjerkan. These pass through the stations marked C_{42}, C_{43} and C_{44} and C_{16}, C_{17}, C_{18} and C_{19} respectively (See the chart Fig. 63). Specially remarkable in these sections are the almost vertical course of the isotherms for 10° and the

isohalines for 35.00‰ outside the banks. The sections also show that low temperatures and salinities are found in over the banks in the uppermost layers.

The region north of the Newfoundland banks was investigated amongst others by D. J. MATTHEWS from the "Scotia" (1914).

Two sections, Fig. 23 a and 23 b., lying respectively across the stations S_{33} and S_{27} and S_{26}, S_{30}, S_{29} and S_{28} marked on the chart Fig. 63, are taken from MATTHEWS' paper. As the most characteristic

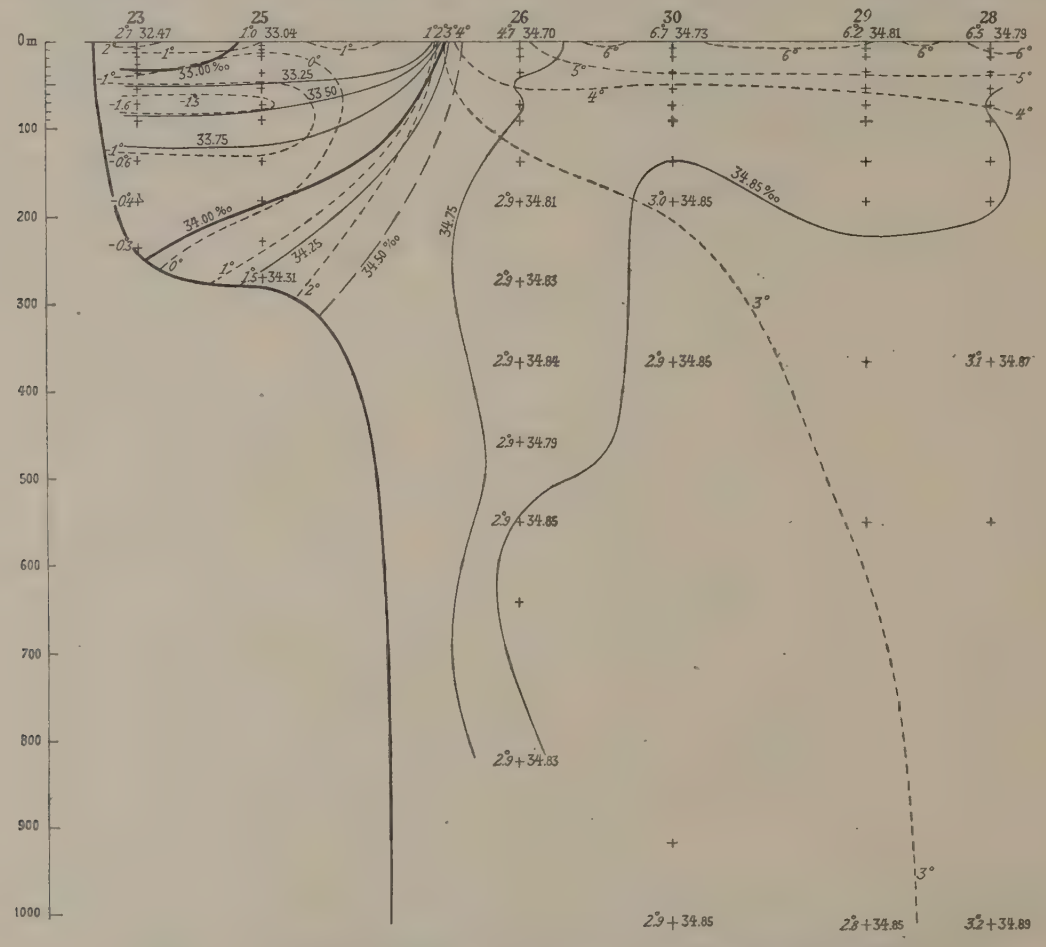


Fig. 23 b. Section north of the Great Bank of Newfoundland reproduced after D. MATTHEWS.

feature of these sections note may be made of the extremely uniform temperature and salinity from the uppermost layers down to the greatest depths in which observations were made (1000 metres). Regarding this uniformity in the temperature and salinity, which holds good for water with a salinity greater than 34‰, MATTHEWS writes (l. c. p. 25): »Nearly the whole of the fall of salinity occurs in the upper 100 fathoms and this fresher surface layer may be due to local precipitation and a slight admixture with Arctic water. In the winter the surface temperatures would be much lower, so that convection currents could arise easily owing to the increased surface density and the water might then be nearly homogeneous. Though the depths are probably well over 1000 fathoms, the water at 550 fathoms, the greatest depth at which observations were made, is not unlike the bottom water of the north-western Atlantic generally, which has

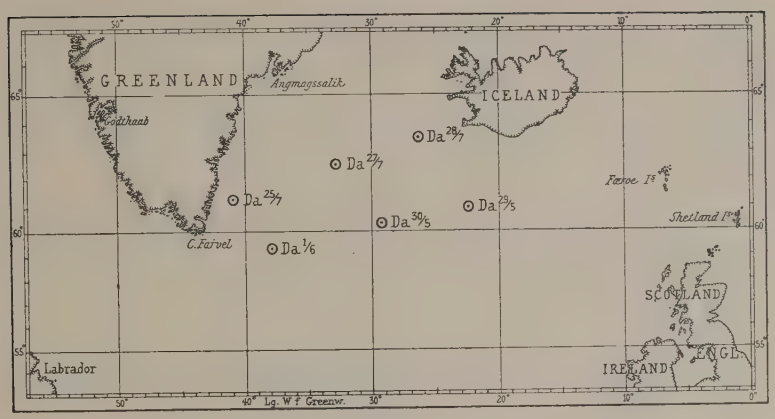
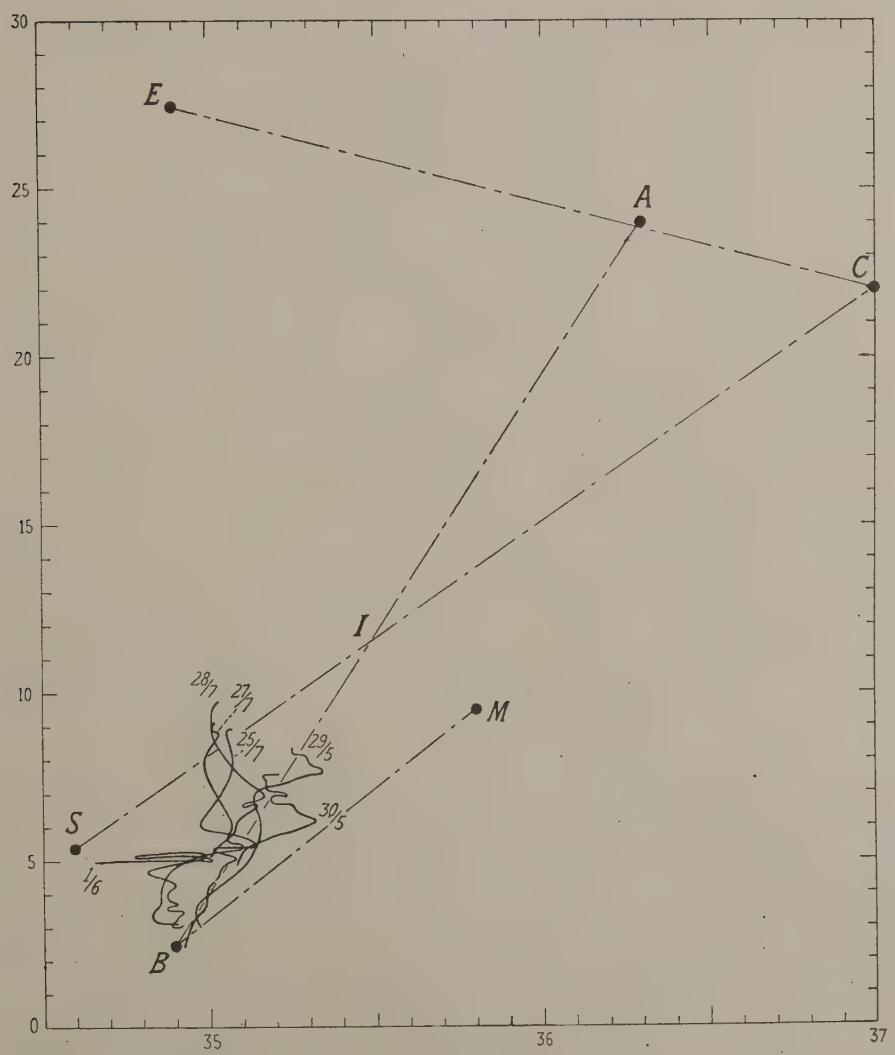

GREENLAND
Angmagssalik
ICELAND
Godthaab
Da 28/7
Da 27/7
Da 25/7
Da 29/5
Da 30/5
Færoe Is
Shetland Is
C. Farvel
Da 1/6
SCOTLAND
ENGL.
IRELAND
Labrador
Lg. W f Greenw.

Fig. 24.


E
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27/7
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5
0
35
36
37

Fig. 25.

a salinity of about 34.90‰ and a temperature of 2.5° according to the observations made by Helland-Hansen on the "Michael Sars" in 1910 (Nansen 1912, p. 14)«.

In the paper referred to of 1912 regarding the origin of the bottom-water in the Atlantic F. Nansen indicates the region south-east of Greenland as the place from which it mainly comes. In this connection it may be of interest to take note of the temperature and salinity distribution at some of the stations investigated in 1925 by Prof. Baggesgaard-Rasmussen from the "Dana". The position of the stations is indicated on the chart Fig. 24 and the temperature, salinity and oxygen contents are noted in Table 14. Further, Fig. 25 shows the temperature and salinity in the form of TS diagram for all stations with a TS curve for each station. From the last figure it will be seen, that the hydrographical conditions in this

Table 14.

	Salinity						Temperature						Oxygen					
Depth m	Da 29/5	Da 30/5	Da 1/6	Da 25/7	Da 27/7	Da 28/7	Da 29/5	Da 30/5	Da 1/6	Da 25/7	Da 27/7	Da 28/7	Da 29/5	Da 30/5	Da 1/6	Da 25/7	Da 27/7	Da 28/7
0..	35.25	35.21	34.65	35.07	35.01	35.03	8.34	7.54	4.97	8.85	8.98	9.72	108	112	103	106	103	106
25..	35	17	85	05	01	01	8.20	7.35	5.14	7.28	8.87	9.04	104	106	101	..	..	..
50..	28	17	99	34.97	03	07	8.13	7.12	5.08	6.02	6.80	7.74	101	100	100	96	97	98
75..	30	23	..	35.14	07	14	8.03	6.91	4.02	5.49	6.03	7.13	100	94	95	...	..	..
100..	30	19	34.90	05	05	17	7.81	6.91	4.23	5.39	5.63	6.92	98	92	94	96	94	92
150..	34	19	88	01	10	14	7.62	6.70	4.05	5.31	5.39	6.72	95	92	90	..	..	..
200..	30	25	87	08	07	10	7.54	6.67	3.83	5.02	5.28	6.62	95	91	93	93	93	92
300..	..	..	90	03	34.90	14	..	..	3.66	4.70	4.81	6.69	..	..	..	91	89	92
400..	35.25	..	87	..	87	11[4])	7.32	6.63	3.54	..	4.54	6.39[4])	95	84	93	..	92	92[4])
600..	..	35.32	92	..	85	07[4])	7.18	6.14	3.43	..	3.93	5.96[4])	94	89	94	..	92	90[4])
800..	35.14	10	90	34.99	85	04[4])	7.02	5.29	3.20	3.60	3.63	5.54[4])	94	83	92	88	91	88[4])
1000..	16	08[1])	90	97	83[3])	..	6.05	4.83[1])	3.17	3.39	3.49[3])	..	77	84[1])	91	90	87[3])	..
1500..	34.96	..	88	94	83	..	3.69	..	3.06	2.99	3.20	..	86	..	91	89	90	..
2000..	97	..	90[2])	..	..	..	3.00	..	3.00[2])	..	..	..	85	..	91[2])	..	..	..

[1]) 975 m. [2]) 1850 m. [3]) 1050 m. [4]) interpolated.

area are by no means simple, yet the TS curves for the greatest depths are running near the lowermost part of the line AB.

The station investigated on 1/6 lies on the eastern border of the region indicated by Nansen or just outside to the east and has a temperature of 3.10°, salinity 34.92‰ and oxygen contents 87% at a depth of 2350 metres. The station of 25/7, which lies to the west of the region indicated by Nansen and only about 45 miles from the east coast of Greenland has the temperature of 2.41°, salinity 34.92% and oxygen 90% at the depth of 1750 metres. It thus looks as if the true bottom-water in the Atlantic with a temperature of about 2.4° and salinity of 34.90‰ rather comes from the water on the continental shelf, which through cooling in winter and formation of ice obtains a high specific gravity, than from the surface water out over the great depths of the ocean. The cooling of this surface water in winter undoubtedly produces the convection currents referred to by Nansen, but these possibly do not reach down to the greatest depths, 3000 metres and more. They may rather be conceived to contribute to the formation of the homogeneous water found by Matthews north-east of Newfoundland. It may be put forward as a possibility therefore, that the true bottom-water in the northern parts of the Atlantic comes from the water along the shelf in the Denmark Straits, which by winter cooling and ice formation obtains such a high specific gravity, that it finds its way as an under-current along the bottom down to the greatest depths. A contribution to the formation of the bottom-water in the Atlantic is also made, as is known,

by water flowing out of the Norwegian Sea over the Faeroe-Shetland and Faeroe-Iceland ridge, even if this contribution is of subordinate importance, as noted by NANSEN.

The question of the origin of the water in the deep parts of the Atlantic, that is from 2.000 metres down to the bottom, is also presumably of the greatest importance from the biological side, but this

Table 15.

	Temperature							Salinity						
Depth m	Mean	S. 26	S. 27	S. 28	S. 29	S. 30	S. 33	Mean	S. 26	S. 27	S. 28	S. 29	S. 30	S. 33
0.....	5.99	4.7	6.9	6.55	6.2	5.7	5.9	34.75	34.70	34.82	34.79	34.81	34.73	34.65
9.....	79	4.61	6.93	12	5.65	5.66	..	75	67	80	78	76	73	..
18.....	56	4.26	77	5.83	46	66	5.38	74	67	81	79	76	74	34.65
37.....	18	4.18	77	28	04	06	4.78	74	67	83	78	76	74	65
55.....	4.50	4.00	40	4.58	4.04	3.71	26	79	81	85	83	79	78	66
73.....	00	3.59	5.73	04	3.37	28	00	80	74	87	87	82	79	68
91.....	3.76	3.36	4.94	3.73	48	20	3.88	80	76	87	83	82	83	69
137.....	54	2.90	5.37	3.36	21	08	32	82	81	87	82	83	85	72
183.....	36	2.90	4.68	3.26	25	04	01	83	83	87	83	84	85	76
274.....	2.88	2.90	..	..	..	..	2.85	82	84	..	..	..	..	81
366.....	3.09	2.87	3.53	3.12	3.06	2.86	..	87	84	34.85	34.87	[34.92]	34.85	..
549.....	09	2.90	55	07	03	..	2.92	85	85	85	87	85	..	34.85
1006.....	2.98	..	13	18	2.81	2.91	88	87	..	90	89	85	34.85	87

Table 16.

Depth	Temperature																	
	C.42	C.43	C.44	C.45	C.46	C.54	C.55	C.56	C.57	C.10	C.11	C.12	C.13	C.14	C.15	C.16	C.17	C.18	C.19
0.....	18.7	17.1	19.7	16.3	17.0	13.9	16.35	17.6	17.5	4.4	5.2	4.55	4.1	8.1	8.1	12.2	11.5	4.8	5.0
25.....	19.2	18.0	21.9	17.65	10.5	11.0	9.4	9.45	10.45	4.25	5.0	-0.3	4.65	7.65	7.95	13.05	11.55	4.1	5.0
50.....	14.35	15.75	19.9	15.2	7.5	5.05	6.35	15.45	6.6	2.2	3.85	-1.15	4.0	6.75	6.65	12.9	11.8	2.8	3.7
75.....	13.15	16.05	17.3	11.75	7.8	4.7	9.85	14.05	4.75	0.8	5.3	-1.7	4.6	7.5	5.8	13.75	12.1	7.3	6.1
100.....	12.2	15.8	13.9	13.0	7.3	4.95	7.85	13.05	5.2	3.5	7.0	-0.65	6.6	8.4	5.8	12.35	12.8	4.0	7.4
125.....	..	..	..	..	..	..	..	..	..	..	6.9	0.4	..	7.0	..	..	..	..	..
150.....	11.65	13.75	11.95	12.2	10.7	7.3	10.1	11.55	6.45	5.85	4.8	3.1	6.0	6.75	6.2	12.25	11.3	4.75	6.4
200.....	10.85	12.95	11.6	11.3	9.4	8.5	8.95	11.35	5.75	5.1	3.8	6.6	5.3	6.35	6.7	10.2	10.9	5.2	6.4
300.....	8.8	11.2	9.45	7.7	8.45	5.3	7.3	9.2	6.8	3.9	3.2	5.2	..	4.7	5.6	10.2	10.8	4.0	5.1
400.....	7.4	8.4	7.5	6.2	6.9	4.9	5.95	7.8	5.5	3.8	2.9	3 7	..	4.7	4.25	9.3	8.8	3.8	5.5

Depth	Salinity																	
	C.42	C.43	C.44	C.45	C.46	C.54	C.55	C.56	C.57	C.10	C.11	C.12	C.13	C.14	C.15	C.16	C.17	C.18	C.19
0.....	34.33	33.69	33.99	33.73	32.46	31.94	32.03	31.65	32.84	32.48	..	32.61	32.19	33.57	33.30	35.01	..	32.89	32.91
25.....	35.11	34.59	35.25	34.28	05	32.66	67	32.72	67	61	32.79	81	89	58	30	25	34.90	88	91
50.....	21	62	35.90	74	33.58	33.45	33.46	35.59	33.30	74	86	82	33.56	60	55	..	35.11	84	84
75.....	38	35.82	99	60	96	87	34.69	..	63	86	33.81	94	85	74	44	35.58	..	34.16	34.22
100.....	33	82	57	35.23	99	93	31	35.42	96	33.69	34.34	33.08	34.43	34.77	34.02	33	35.39	33.82	47
125.....	..	..	..	..	..	..	..	..	..	..	49	24	..	34.69	..	..	..	..	..
150.....	35.43	35.62	35.35	35.40	35.15	34.69	35.20	35.37	34.56	34.40	39	79	34.59	70	34.43	..	35.25	34.21	34.40
200.....	40	47	44	34	34.92	96	01	35	61	..	..	..	61	..	..	35.05	..	..	..
300.....	12	42	25	08	35.23	89	34.88	21	35.06	34.49	34.33	34.49	..	34.67	34.68	24	35.31	34.56	34.54
400.....	09	12	11	04	34.94	93	95	01	34.98	67	42	45	..	75	61	21	02	68	61

aspect will not be discussed as it belongs to a different series of problems to those dealt with here. In brief we shall assume, that the water in the North Atlantic mainly comes from the regions mentioned by NANSEN east and south-east of Greenland or their neighbourhood, possibly in on the continental shelf, and that as already indicated it is characterized by the salinity 34.90‰ and temperature 2.5° (in situ).

On the basis of the observations from the expeditions above-mentioned: "Scotia" 1913, Canadian Fisheries Expedition 1914—15 and observations from the Ice Patrol Service, a more detailled account may now be given of the hydrographical conditions in the western part of Area I.

Tables 15 and 16 show the temperatures and salinities from selected stations with depths greater than 500 metres of the "Scotia" and the Canadian Expedition. The stations are marked in the tables with respectively S and C and their positions on the chart Fig. 63 are noted with the same letters. The chart Fig. 63 likewise indicates the positions of a number of stations with depth greater than 500 metres selected from the observations of the Ice Patrol Service 1924 and 1925. Most of these are without a mark, but a few have the number given in the publication, thus 389, 429, 499, 501, 502 and 507.

In Fig. 26 the temperatures and salinities at the selected stations are recorded in a TS coordinate system, but we have only included observations from depths of 100 metres and more at which the salinity has been greater than 34‰. Various signs indicate the different observations, a) west of 60° W. L., b) between 60° W. L. and 54° W. L., c) east of 54° W. L. and d) the stations of s/s. Scotia.

With regard to the meaning of the signs and the number of the observations within certain groups reference may be made to the text belonging to Fig. 26. As will be seen, several of the observations noted in the figure are accompanied by the depths from which they came.

The diagram shows that within the Area considered the water has greatly varying temperatures and salinities, which may come as mentioned partly from melting ice, partly from the water of the Gulf of St. Lawrence. Specially remarkable is the fact, that almost all the observations taken by the "Scotia" are situated within the area in Fig. 26 with temperatures between 2.6° and 3.4° and salinities between 34.76 and 34.94‰, thus near to the temperature and salinity found in the great depths of the North Atlantic.

The observations made by the Canadian Fishery Expedition and Ice Patrol Service vary greatly in temperature and salinity and many of them show a low salinity, especially in the upper layers. On the slope of the Great Bank, where most of the Ice Patrol stations were situated, we find water in depths between 450 and 800 metres which has relatively high salinities in the neighbourhood of 34.85‰ and temperatures in the neighbourhood of 4°, thus but little different from the water found at the "Scotia"s stations.

At the stations along Nova Scotia and along the banks we find water in depths from 100 to 450 metres with such a distribution of temperatures and salinities, that in Fig. 26 they form a belt inclined upwards to the right.

In the figure a straight line is drawn to represent the different kinds of mixtures of A-water ($T = 24°$, $S = 36.3‰$) and B-water ($T = 2.5°$, $S = 34.9‰$), and we see that this line runs mainly along the right of the belt of points, which indicate the temperatures and salinities of the water between 100 and 450 metres along the southern slope of the Nova Scotia and Newfoundland banks. We may conclude therefore, that this water is mainly formed by a mixture of A-water and bottom-water, or water which is found at the "Scotia"s stations with a slight admixture of water of less salinity. That AB-water with a considerably greater amount of A-water than that of J-water ($T = 11.5°$, $S = 35.5‰$) is only found in a few cases, is due to the earlier mentioned condition, that AB-water with high temperature and high salinity forms with water of low salinity a surface mixture which has a northerly and easterly movement. (See p. 34).

According to the diagram the highest temperatures and salinities of the AB-water, which is generally found in the region of the Newfoundland banks, may be placed at respectively ca. 13° and 35.6‰, but higher values for the temperature and salinity of the AB-water may also occur, as indicated for the

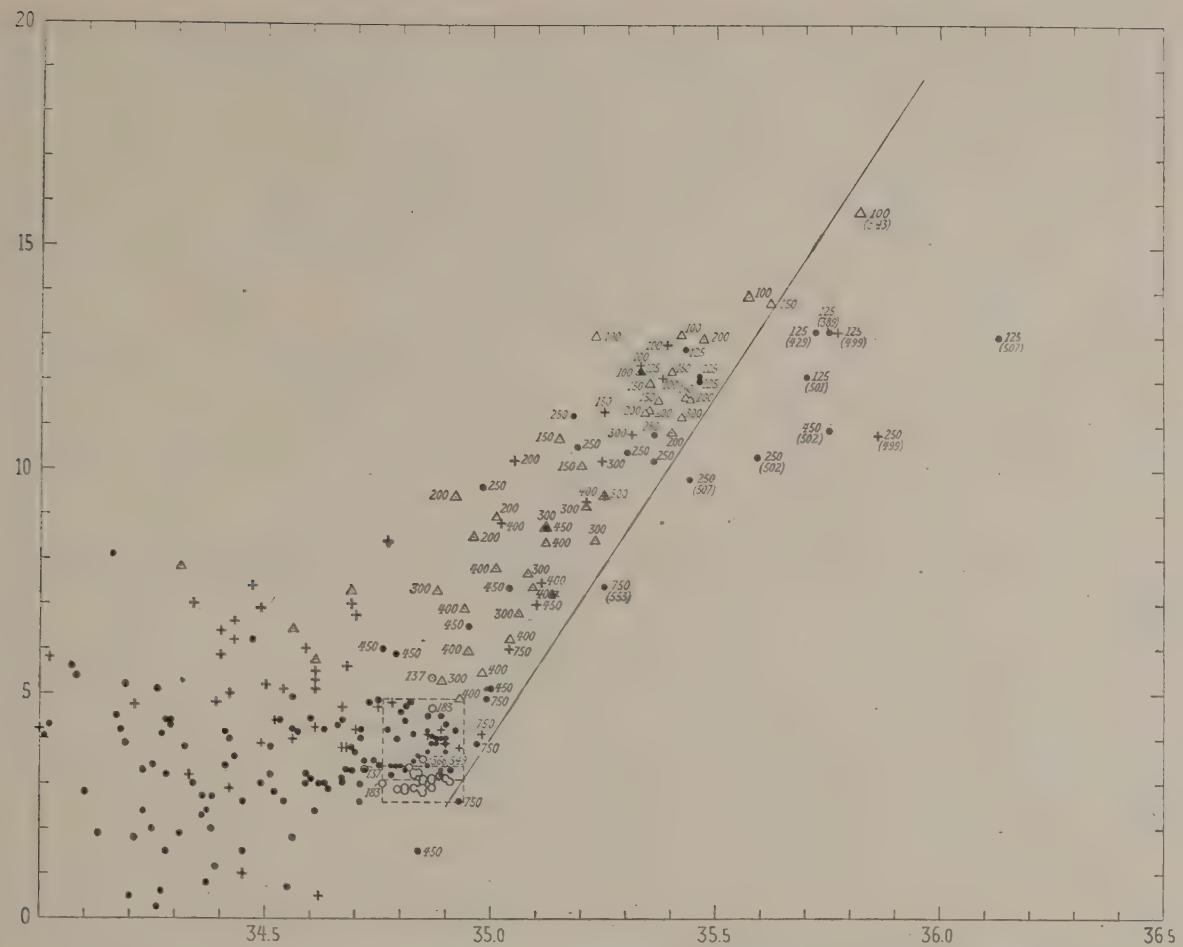

Fig. 26. TS Diagram showing the connection between temperature and salinity for observations published in:

1) Report on the work carried out by s.s. "Scotia" by D. J. Matthews 1913. London 1914. — The observations were taken in June and July 1913.
2) Results of the Hydrographical Observations made by Johan Hjort in Canadian Atlantic Waters during the year 1915 by Paul Bjerkan, Bergen, Norway. — The observations were taken in May, June and July 1915.
3) International Ice Observation and Ice Patrol Service 1925 by Edward H. Smith. — The observations were taken in March, April, May and June 1924 and 1925.

In the diagram observations are only plotted from stations with depths of 500 m or more and at these stations observations only from a depth of 100 m or more with a salinity of 34.00 ‰ or more.

Observations from the above mentioned publication (1) are indicated by ○, Observations from publication (2) west of 60° W. L. are indicated by △ (observations only at hand from July), Observations from publications (2) and (3) between 60° W. L. and 54° W. L. are indicated by + and observations from publication (3) east of 54° W. L. are indicated by ●.

For some of the observations plotted in the diagram the depths are indicated.

In the area of the diagram with temperatures from 3°,1 to 4°,9 and salinities from 34.76 ‰ to 34.94 ‰ are found 40 pairs of observations viz.

from	250	metres	2	obs.	marked	●		
—	450	—	10	—	—	●	and 3 marked	+
—	750	—	22	—	—	●	— 2 —	+
—	800	—	1	—	—	●		

In the area of the diagram with temperatures from 2°,6 to 3°,4 and salinities from 34.76 ‰ to 34.94 ‰ are found 26 pairs of observations from "Scotia" marked ○

viz. from metres	137	183	294	366	457	549	640	823	1006.
pairs of observations	4	4	2	4	1	4	1	1	5.

Stat. C 44 on the diagram Fig. 21. On the other hand, huge water-masses of AB-water with temperatures and salinities lower than ca. 13° and 35.6‰ occur in the Newfoundland region from about 100 metres down to the greatest depths, and the formation of these water-masses may be ascribed to an essential, perhaps to the greatest, part to the water of the Florida and Antilles Currents, whilst the remaining part of these currents is carried away as surface mixture with water of low salinity.

The mixture referred to here as AB-water includes a mixture of A-water with the deep water found at the "Scotia"s stations, which has a somewhat higher temperature than the B-water. This mixture possibly contributes specially to the formation of the intermediate layers at a depth of about 3.000 metres in the North Atlantic.

Fig. 26 shows that water is found at some places with temperatures and salinities represented by points, which lie to the right of the line indicating the AB-water. At these points are indicated the stations from which the observations come and it will be seen from the chart Fig. 63, where the stations discussed are marked, that they all with exception of C 43 and 499 lie on the south-eastern slope of the Great Bank of Newfoundland. Stat. C 43 comes from the Canadian Fishery Expedition, the others from the Ice Patrol Service.

Apart from possible errors of observation the explanation of the position of the points to the right of the line in diagram Fig. 26 is certainly this, that at the stations in question an infusion of water has taken place from the neighbouring Area II, where we find a mixture of S-water and C-water with high salinities.

It may be concluded, that the CS-water present in the Areas II and XX advances to some extent to the Newfoundland region and there the CS-water with temperatures and salinities higher than those of the J-water as also the AB-water with high temperatures and salinities become mixed with the water of low salinity present in the Newfoundland region. The surface water formed in this way moves towards the north-east and composes a part of the cyclonic system between Greenland and Newfoundland. To the east this system extends to the eastern boundary of Area I to ca. 50° N., 30° W.

When, as mentioned, the AB-water and SC-water with high temperature and high salinity are mixed with surface water of low salinity and carried away as surface mixture, an elevation of the isotherms and isohalines takes place and these obtain the known oblique position as shown in section IX (Fig. 10). The fields of force which condition the Atlantic Current (Gulf Stream) are thus formed in the neighbourhood of the Newfoundland region.

Even the J-water, which may consist partly of AB-water, partly of CS-water and partly of surface mixtures (p. 34), also obtains a movement towards the north-east, but continues this over to the British Isles, owing partly to the fields of force present, partly to the prevailing westerly winds. The transition from the J-water to the C-water is found about 40° N. Lat., the 36‰ isohaline on the surface following rather closely this degree of latitude.

Just as a mixing with the water-masses present in the Newfoundland region takes place to the east of the A-water carried by the Florida and Antilles Currents, so a mixture of the A-water is formed with the water-masses to the west on the east coast of America. This mixture has a southgoing movement along the east coast of America and can be detected at least as far as Cape Hatteras and possibly farther south.

Stat. 1349 is situated in this mixture and as the diagram Fig. 17 shows, we find here water at a depth of ca. 200 metres which has almost the same temperature and salinity as the J-water, whilst water with a low salinity is found in the uppermost layers.

From the J-water and B-water a mixture is formed which owing to its greater density has been able to displace the CS-water. During the sinking of the JB-water, however, an intensive mixing with the CS-water has taken place, so that between 200 and 900 metres we find a mixture of JB- and CS-water, whilst the layers below 900 metres consist essentially of B-water. This descent of the water outside the

continental shelf off Cape Hatteras has already been noticed by H. B. Bigelow (1917) and has been previously mentioned on p. 19.

In the eastern part of Area I the chart Fig 63 shows the four stations HN 6, M $^5/_8$, HN 83 and HN 85. Those marked HN are taken from the work of Bjørn Helland-Hansen and Fridtjof Nansen on the Eastern North Atlantic, M $^5/_8$ from the Danish expedition of the "Margrethe" in 1913. The temperature, salinity and oxygen contents at these stations are noted in Table 17 and Fig. 27 gives the TS diagrams for the same stations.

Table 17.

Depth m	Temperature				Salinity				Oxygen	
	H.N. 83	H.N. 85	H.N. 6 (1913)	M $^5/_8$	H.N. 83	H.N. 85	H.N. 6 (1913)	M $^5/_8$	H.N. 6 (1913)	M $^5/_8$
0	15.8	16.4	12.70	16.21	35.53	35.64	35.02	35.03	109.1	108.2
25	15.4	16.2	11.28	(13.18)	52	63	06	(34.97)	110.9	..
50	14.0	16.0	9.68	10.15	54	62	14	35.01	92.3	..
75	12.7	13.5	(8.65)	(8.97)	53	60	(35.12)	(35.00)	..	..
100	12.0	12.0	13	8.40	51	55	35.09	34.97	92.1	89.0
200	11.5	11.3	7.53	7.10	47	42	08	97	91.1	82.0
300	11.1	10.5	6.57	6.35	40	33	34.96	94	86.3	81.8
400	9.5	9.5	5.73	5.52	18	18	90	94	88.8	81.5
500	7.8	7.7	18	(5.41)	34.99	34.96	90	(34.96)	86.3	..
600	6.6	6.6	02	37	92	89	95	34.97	78.8	78.9
800	5.0	5.0	4.04	(5.25)	90	90	90	97	88.5	..
1000	4.4	4.5	3.97	5.04	94	95	89	92	85.1	..
1200	3.9	4.0	54	(4.83)	93	..	89	(34.97)	86.1	(74.0)
1600	3.5	3.6	29	(4.18)	90	..	88	(34.93)	88.6	..
2000	..	..	41	3.39	..	..	90	34.94	86.9	85.8
2500	..	..	08	36	..	..	99	96	84.1	84.6
3000	..	..	2.83	..	..	..	97	..	82.0	..

The figures in parentheses are graphically interpolated.

We see that the deep water mainly consists of unmixed B-water at all four stations. Mixed B-water, similar to that found at stat. S 28 (see Table 15) in depths greater than ca. 100 metres with temperatures below 4°, is found at stat. HN 6 in depths greater than ca. 900 metres and at the remaining stations in somewhat greater depths. Above the depth in which the 4° isotherm lies, the water is not of the same origin at the four stations mentioned. At the stations HN 6 and M $^5/_8$ the salinity is fairly uniform with values in the neigbourhood of 35 $^0/_{00}$ from the surface to the depths at which the temperature decreases to 4°. There is an oxygen minimum for both stations at an intermediate depth, for stat. HN 6 at 600 metres (78.8 $^0/_0$) and for stat. M $^5/_8$ at 1.300 metres (74 $^0/_0$); otherwise most of the oxygen determinations lie between 80 $^0/_0$ and 90 $^0/_0$ apart from the surface layers.

We may conclude from this, that the uppermost water-layers at these two stations down to water with temperatures lower than 4° are formed by a mixture of an upper layer consisting of A-water mixed with water of low salinity and B-water or water of very similar properties. The different mixtures have then arranged themselves in a vertical direction according to their specific gravities, which are in the main determined by the temperature. So far as the uppermost layers are concerned, we see that heating from the atmosphere has occurred especially at stat. M $^5/_8$. The oxygen minimum in the intermediate layers has thus arisen from the fact, that the oxygen consumption in the deeper layers is counteracted by a comparatively rapid renewal of the B-water in the lowermost layers.

A contrast to these water-layers at stat. HN 6 and M $^5/_8$ is shown by the corresponding layers at the stations HN 83 and HN 85, which lie in the south-eastern part of the Area not far from stat. M $^5/_8$.

At these stations the TS curves for depths between 100 and 500 metres follow very closely the line CS and the water occurring in these depths is certainly for the most part CS-water. No part of this water has however higher temperatures and salinities than those characteristic of the J-water and the uppermost layer of the mixed water from 100 to 300 metres may especially be considered to contain a consid-

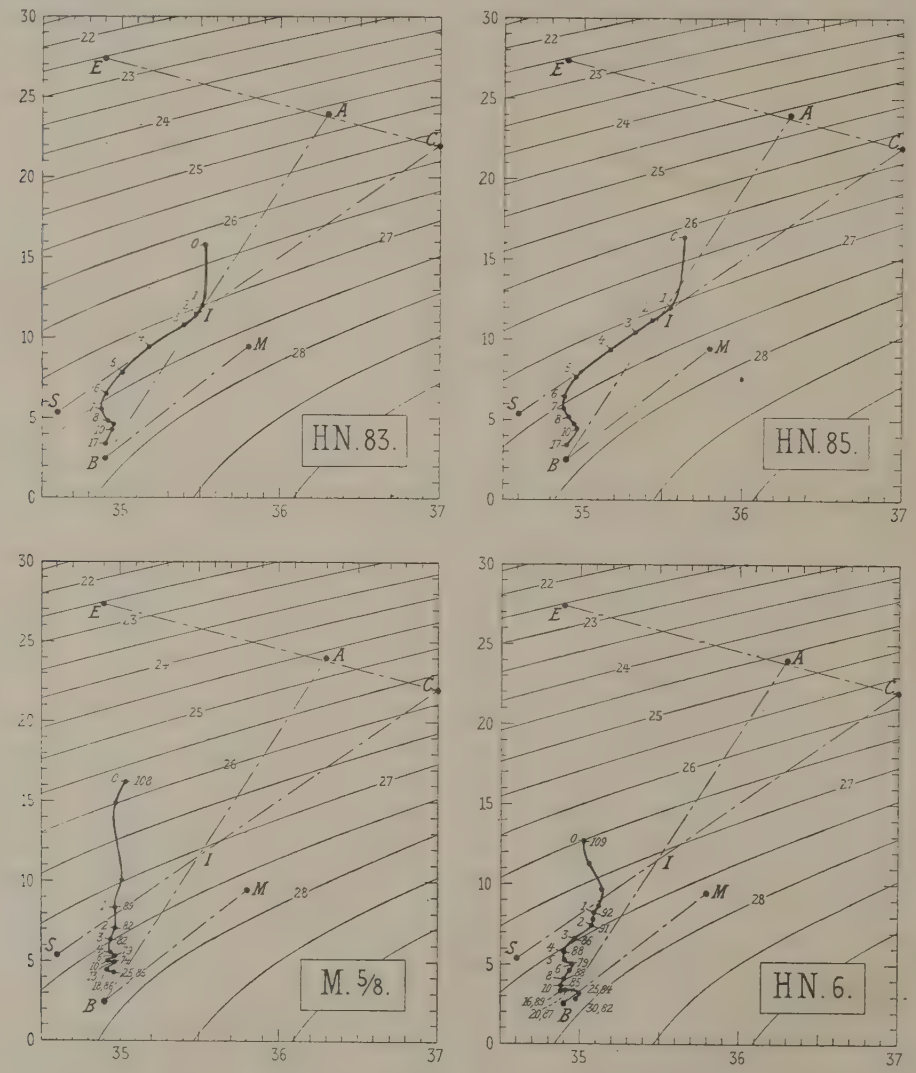

Fig. 27.

erable quantity of J-water, which may well be CS-water, but also AB-water. Between the surface and a depth of 100 metres we find water with higher temperatures than those of the J-water, due to the J-water present being heated from the atmosphere.

Area II is situated to the south of Area I at about 40° N. and 45° W.

We have four stations in this area; MS 65 and MS 63 from the "Michael Sars" Expedition of 1910 (Helland-Hansen 1912), M $^{13}/_{8}$ from the Danish expedition with "Margrethe" in 1913 (Jacobsen 1916)

and D 6 from the German Antarctic Expedition of 1911—12 (Brennecke 1921). The position of the stations is shown on the chart Fig. 63.

For the four stations Table 18 gives the average values of the temperature, salinity and oxygen contents, for the different depths. Further, in Fig. 28 TS curves are given for each of the four stations in the same coordinate system, so that similarities and differences in the curves can be clearly seen. The same coordinate system includes the average values for the temperature and salinity noted in Table 18 and the recorded points are marked with the appropriate depths in hectometres. The figure shows the lines AB, CS etc. for the different kinds of mixtures just as in the TS diagrams previously given, but the isodense curves are not included, for the sake of space.

Similar methods of describing the conditions by means of tables and TS curves, as used here for Area II, have also been employed for most of the following areas to be mentioned.

The station farthest to the west in Area II, namely stat. MS 65, has already been mentioned (p. 47) in connection with the TS diagram given for this station in Fig. 21. Between 100 and 800 metres we find CS-water, between 1,000 and 2,000 metres JB-water and between 800 and 1,000 metres a mixture of JB-water an CS-water. Similar conditions are found at the stat. M 63 more to the south and east, but the mixture of the JB- and CS-waters here lies between 700 and 900 metres and has a somewhat different character than at Stat. 65 with greater stability.

At stat. MS 63 observations were made down to a depth of 4,000 metres and there unmixed B-water was found ($T = 2.4°$, $S = 34.88‰$),

At the stat. M $^{13}/_{8}$ from the Danish expedition with the "Margrethe" in 1913, which lies in the eastern part of the Area, we find CS-water from 100 metres down to about 800 metres just as in the western part of the Area. That the TS curve lies somewhat below the line CS may possibly be due to some extent to the fact, that the observations were made under somewhat primitive conditions and are thus not quite reliable. It may be remarked however, that the salinity of the CS-water in 100 metres (35.9‰) is considerably lower than the salinity of the CS-water (36.3‰) at the same depth in the western part of the Area.

At the greatest depth investigated (2,000 metres) JB-water was found which is essentially B-water. The oxygen contents at this depth amount to 80 %. Between 1,200 and 2,000 metres lies a mixture which consists essentially of the JB-water at 2,000 metres and M-water. At 1,200 metres the M-water is most prominent. Here the oxygen amounts to 71.6 %. Between 800 and 1,200 metres there is a mixture of CS-water and the mixture occurring at 1,200 metres. The oxygen minimum occurs in the very stable, mixed water at 1,000 metres (67.6 %).

In the most easterly part of the Area near stat. M $^{13}/_{8}$ lies stat. D 6 from the German Antarctic Expedition of 1911. Here CS-water was found from 100 down to about 700 metres, almost as at stat. M $^{13}/_{8}$. On the other hand, the TS curve for stat. D 6 shows that JB-water occurs between 1,000 and 2,550 metres without admixture of M-water. Between 700 and 1,000 metres there is a mixture of CS-water and JB-water. The oxygen minimum is found at a depth of 100 metres with 66 %.

The characteristics of Area II may therefore be stated as follows. In depths between 100 and 700—800 metres CS-water is found; in deeper layers from ca. 1,000—1,200 metres down to the greatest depths there is JB-water, with which in the eastern part there may be mixed M-water. In intermediate depths about 900 metres we find a water-layer with a thickness of 300—400 metres, which consists of an admixture of CS- and JB-waters. The oxygen minimum occurs in this water-layer.

Area III about 33° N. and 40° W.

The stations of the "Dana" Expedition belonging to this Area, 1362, 1365 and 1367, have been discussed in detail earlier (p. 35—36 and Fig. 17) along with the selected TS-diagrams. In keeping with the

method of treatment for Area II, Table 18 below gives for this Area the average values of the hydrographical data and in Fig. 29 p. 63 the TS diagrams are brought together in a single figure.

As characteristic of Area III it may be said, that the water from 100 down to 700 metres consists of CS-water, which in contrast to the water of Area II has higher temperatures and salinities. In the western part of the Area we find unmixed C-water at stat. 1362. B-water occurs in the greatest depths of 3000 metres and more. Between 700 and 3000 there is a mixed water, which contains greater or smaller quantities of JB-water, CS-water and M-water according to the depth. An infusion of the last is most

Table 18.

Depth m	Area II			Area III			Area IV			Area V		
	Temp. Mean	Salin. Mean	Oxyg. Mean	Temp. Mean	Salin. Mean	Oxyg. Mean	Temp. Mean	Salin. Mean	Oxyg. Mean	Temp. Mean	Salin. Mean	Oxyg. Mean
0.....	20.72	36.18	105.2	21.85	36.69	102.2	23.86	37.26	101	24.84	37.26	100.9
25.....	21.00	38	..	21.37	66	104.0	22.77	20	98	24.44	22	103.2
50.....	17.84	14	101	20.09	64	106.0	22.20	18	100	23.46	14	100.5
75.....	17.80	34	..	19.10	57	103.0	21.40	13	101	22.42	12	101.1
100.....	15.88	11	95	18.68	54	100.3	21.03	07	97	21.67	07	99.2
125.....	17.10	33	..	18.11	46	93.4	..	..	..	21.70	09	97.6
150.....	16.85	29	..	17.60	39	90.5	18.34	36.58	86	19.53	36.71	87.4
200.....	15.04	04	92.2	17.16	34	91.7	18.07	60	84	18.15	55	82.4
300.....	14.86	00	87.9	16.32	24	88.3	..	..	..	17.11	38	83.2
400.....	13.77	35.80	83.8	15.29	06	84.5	14.64	36.00	70	15.17	06	72.5
500.....	13.95	78	..	13.73	35.81	77.3	..	..	..	13.88	35.86	71.6
600.....	11.70	49	83.0	12.51	64	73.5	11.46	35.58	61	11.93	61	62.3
700.....	10.20	27	..	10.59	42	66.8	..	..	..	10.80	44	55.8
800.....	8.48	20	67.4	9.45	35	64.6	9.53	35.38	52	8.68	21	50.8
900.....	7.00	16	..	8.25	29	64.6	..	..	..	..	..	..
1000.....	6.46	15	69.3	7.45	27	69.3	7.07	35.14	52	6.31	35.00	52.8
1200.....	5.41	10	74.8	6.00	23	75.0	6.19	10	57	5.38	34.99	65.0
1500.....	4.31	00	80.6	5.03	17	81.0	5.19	12	68	4.63	35.02	71.5
2000.....	3.78	34.96	81.9	3.74	02	84.6	4.01	04	73	3.82	03	76.0
2500.....	3.26	92	84	3.34	00	82.8	..	..	..	..	..	..
3000.....	2.90	92	..	3.02	34.93	81.5	2.83	34.96	73	2.88	34.98	72.0
3500.....	2.60	90	..	2.77	93	80.9	..	..	..	..	..	..
4000.....	2.35	88	..	..	..	..	..	..	..	..	..	..
4500.....	..	..	..	..	..	..	..	..	..	2.49	..	..
5000.....	..	..	..	..	..	..	2.46	34.88	..	..	..	..

distinct at stat. 1365. For the rest, reference may be made to the previous discussion of the TS diagrams for the stations mentioned (p. 35—36).

Area IV about 27° N., 35° W.

In this Area we have the stations D 13, D 14 and D 15 from the German Antarctic Expedition of 1911—12 (Brennecke 1921). Their position can be seen from the chart Fig. 63. The hydrographical material from the stations is shown in Table 18 and Fig. 30 in a similar manner as for the preceding areas II and III. Stat. D 14 has already been mentioned in connection with the treatment of the selected TS diagrams (p. 43 and Fig. 18).

The TS curves for the three stations have very nearly the same course. In agreement with the definition of C-water (see p. 30) they show that unmixed C-water occurs at a depth of 100 metres. From 100 to ca. 800 metres we find CS-water with salinity varying from 37 ‰ to ca. 35.4 ‰. From 800 metres

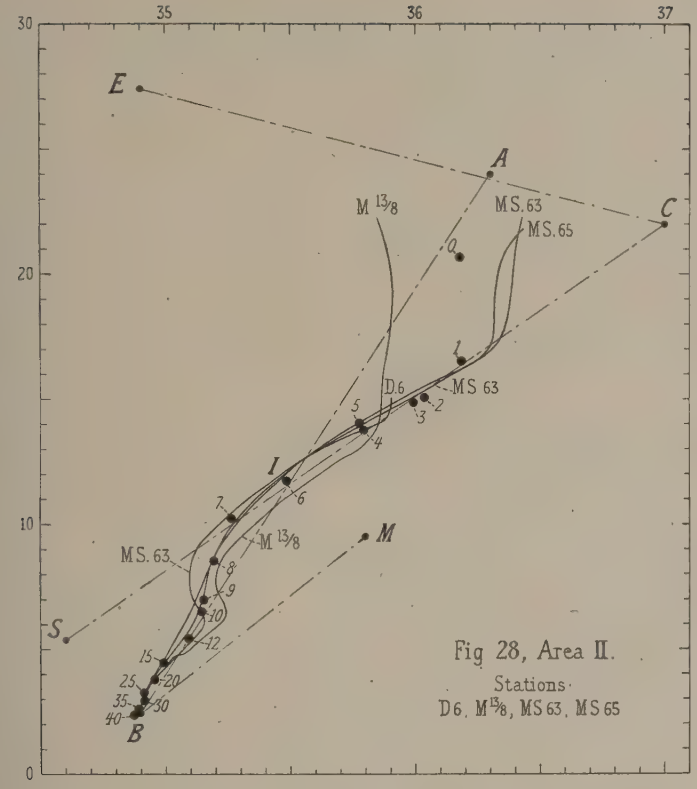

Fig 28, Area II.
Stations
D6, M 13/8, MS 63, MS 65

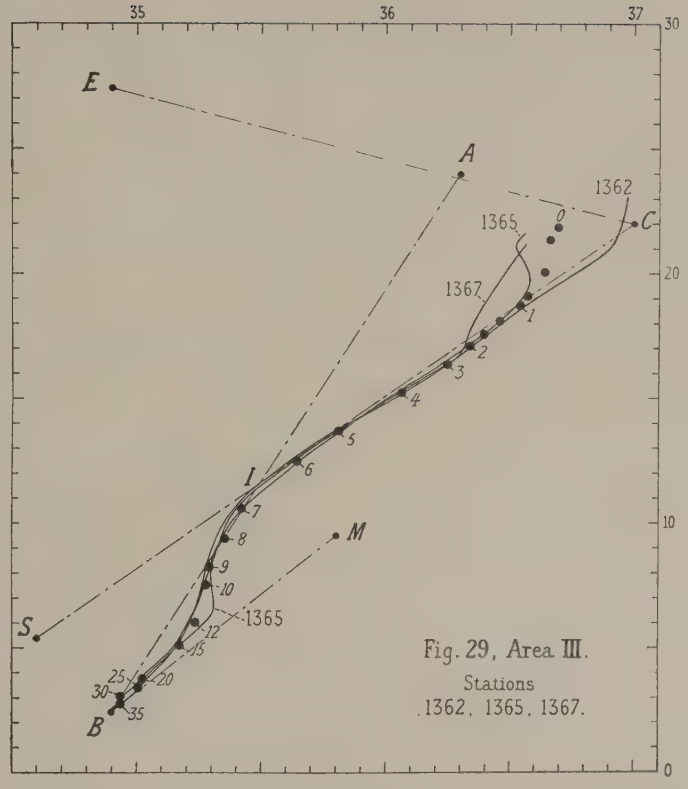

Fig. 29, Area III.
Stations
1362, 1365, 1367.

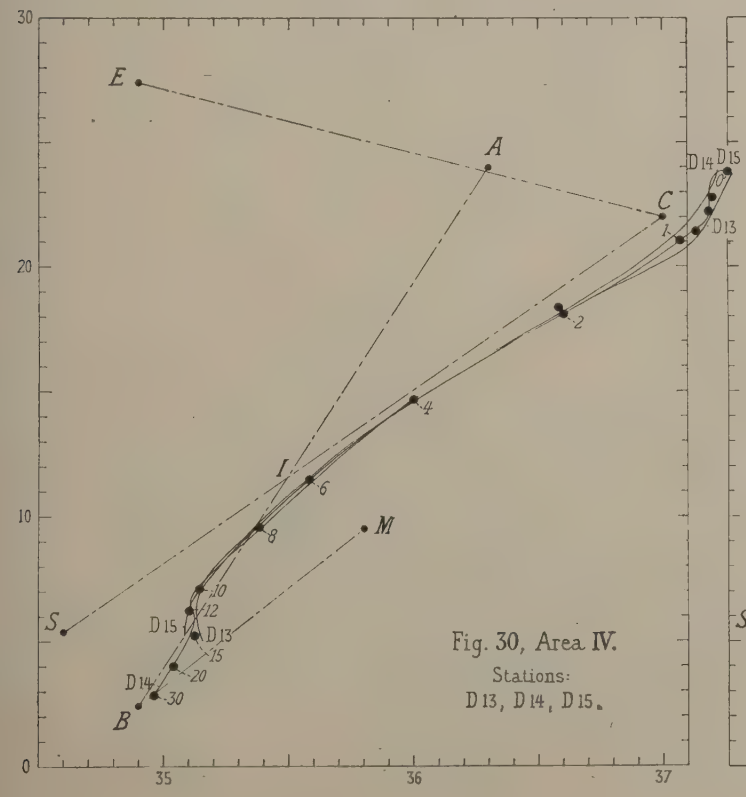

Fig. 30, Area IV.
Stations:
D13, D14, D15.

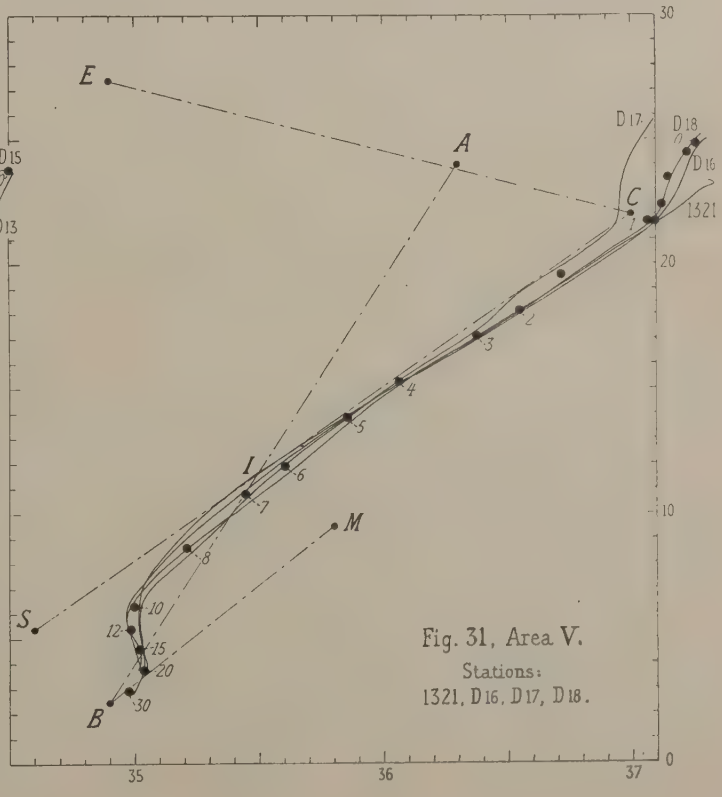

Fig. 31, Area V.
Stations:
1321, D16, D17, D18.

down to the greatest depths we find a mixture of JB-water with both S-water and M-water. The influence of the last is however less than in Area III to the north. The oxygen minimum of ca. 52 % is found at a depth of 800—1000 metres, in part due to the influence of the S-water, in part presumably to the comparatively slow renewal of the water at this depth.

Area V about 22° N., 45° W.

In this Area lie the stations D 16, D 17 and D 18 of the German Antarctic Expedition of 1911—12 (BRENNECKE 1921) and stat. 1321 of the "Dana" Expedition (see chart Fig. 63). The material from these

Table 19.

Depth m	Area VI			Area VII			Area VIII			Area IX		
	Temp. Mean	Salin. Mean	Oxyg. Mean	Temp. Mean	Salin. Mean	Oxyg. Mean	Temp. Mean	Salin. Mean	Oxyg. Mean	Temp. Mean	Salin. Mean	Oxyg. Mean
0.....	25.41	35.68	96.5	15.06	35.53	105.3	15.72	35.70	108.8	19.54	36.21	103.0
25.....	25.74	81	96.4	14.35	53	104.5	15.59	69	110.3	18.56	17	104.6
50.....	25.88	36.07	97.4	12.35	54	100.0	13.25	66	105.0	16.79	12	106.2
75.....	25.55	67	99.0	11.62	53	98.0	12.53	68	99.7	16.00	12	103.4
100.....	24.62	92	96.0	11.20	51	97.1	12.17	64	96.6	15.45	08	99.7
125.....	23.15	98	97.7	10.97	49	96.4	..	..	..	15.32	07	96.1
150.....	21.95	93	86.6	10.83	48	95.7	12.18	35.66	96.5	14.61	35.98	94.6
200.....	19.38	72	75.0	10.62	46	95.1	11.82	62	96.1	14.21	92	90.6
300.....	17.05	35	76.4	10.26	42	93.6	11.54	58	96.6	13.02	77	86.6
400.....	14.09	35.84	55.2	9.92	38	92.9	11.00	52	91.6	12.26	67	82.8
500.....	12.67	63	57.4	9.51	34	88.1	10.70	48	83.2	11.39	57	81.3
600.....	10.26	30	47.7	9.09	29	86.7	10.30	46	83.2	10.79	50	77.6
700.....	..	..	..	8.44	24	80.2	9.75	42	76.9	10.09	50	72.8
800.....	7.12	34.95	45.2	7.67	19	74.3	9.39	44	76.8	9.67	50	70.1
900.....	..	..	..	7.00	17	75.6	8.80	46	71.6	9.30	58	70.3
1000.....	5.61	34.90	52.4	6.41	15	75.3	8.50	52	71.2	8.57	53	69.8
1200.....	5.01	35.00	68.0	5.10	06	77.5	7.22	42	74.7	7.03	45	73.9
1500.....	4.40	34.99	71.5	4.04	34.97	83.3	5.70	21	76.2	5.54	22	79.1
2000.....	3.62	96	77.6	3.43	93	87.0	3.71	34.98	84.0	4.22	03	83.2
2500.....	3.12	96	75.2	3.25	94	85.0	3.20	96	82.3	3.67	34.95	85.1
3000.....	2.76	94	77.6	3.02	94	79.0	2.92	97	77.0	3.73	92	80.2
3500.....	2.48	92	77.4	2.70	95	..	2.70	91	75.9	3.46	98	78.2
4000.....	2.47	92	74.8	..	..	..	2.54	91	78.2	..	..	..
4500.....	2.36	93	76.8	..	..	..	2.56	98	78.9	..	..	..
5000.....	2.55	94	79.0	..	..	..	..	..	..	..	..	..

stations has been dealt with in Table 18 p. 62 and Fig. 31 in the same manner as for the preceding areas. In agreement with the definition of C-water (see p. 30) this is found at a depth of 100 metres. From this depth down to ca. 800 metres we find CS-water just as in Area IV, but here with salinities right down to ca. 35.2 ‰, the S-water making its influence more felt in this Area than in the previous ones. At the greatest depths we as usually find B-water and in 2000 metres mainly B-water with some admixture which may possibly be a small quantity of M-water, but more likely J-water. Between 800 and 2000 metres there is a mixture of CS-water and the somewhat diluted B-water.

The oxygen minimum (ca. 51 %) is found at 800 metres, almost as in Area IV. Yet the oxygen contents at 800 metres are lower at the most southerly of the stations dealt with, stat. D 18, than at the other stations, reaching down to 47 %. This is undoubtedly connected with the fact, that the S-water is less mixed at this station than at the others.

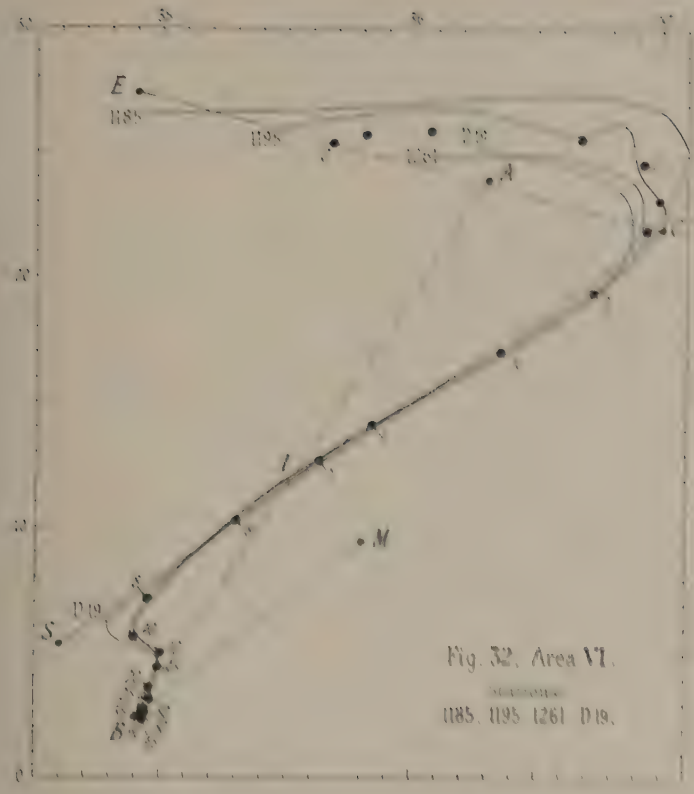

Fig. 32. Area VI.

Stations.

1185, 1195, 1261, D19.

Fig. 33. Area VII

Stations.

Th60, M[illegible], HN4a, HN5, HN59, HN60, HN61, HN80, HN82, HN88a, HN62

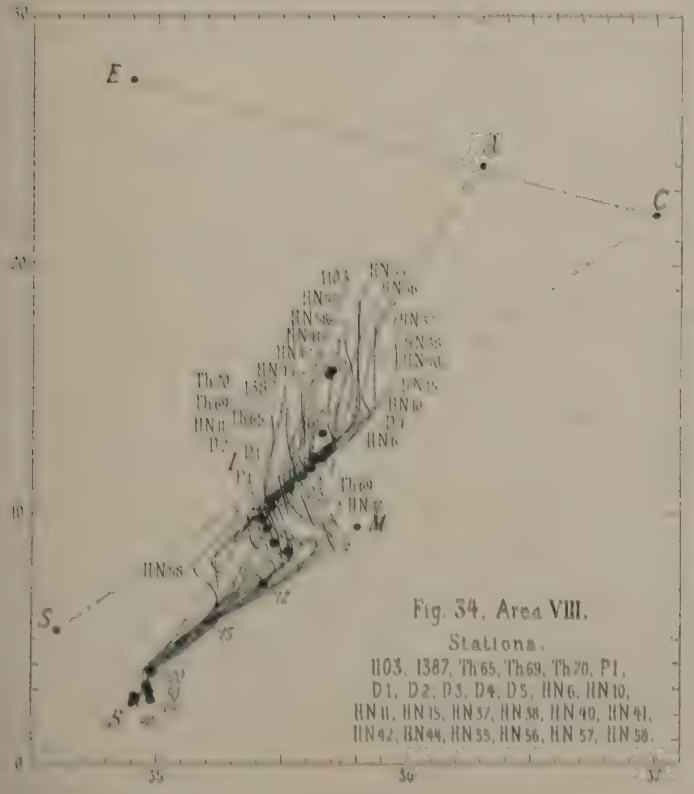

Fig. 34. Area VIII.

Stations.

1103, 1387, Th65, Th69, Th70, P1, D1, D2, D3, D4, D5, HN6, HN10, HN11, HN15, HN57, HN58, HN40, HN41, HN42, HN44, HN55, HN56, HN57, HN58.

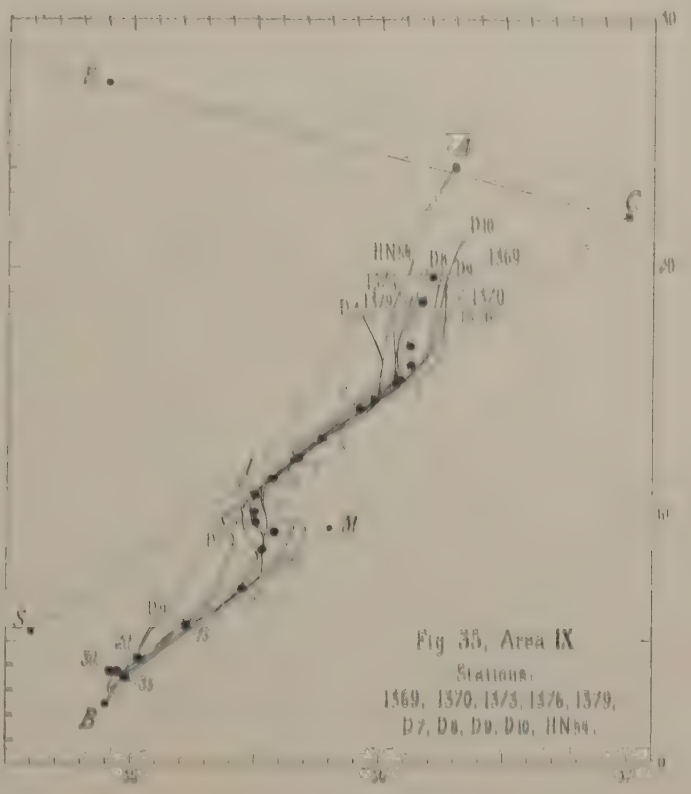

Fig. 35. Area IX

Stations.

1369, 1370, 1375, 1376, 1379, D7, D8, D9, D10, HN54.

Area VI lying north and east of the Caribbean Islands.

In this Area we have stat. D 19 from the German Antarctic Expedition of 1911—12 (BRENNECKE 1921) and the stations 1185, 1195 and 1261 of the "Dana" Expedition (see chart Fig. 63). Of these stations D 19 and 1261 have already been mentioned (see Fig. 18 and 20) in dealing with the selected TS diagrams. The material from the stations mentioned has been treated in the same manner as for the Area II and following areas (see Table 19 p. 64 and Fig. 32 p. 65).

In Area VI the CS-water in various conditions of admixture is still more prominent than in the immediately preceding areas, occuring in depth from 150 to 800 metres with salinities from ca. 37 ‰ to less than 35 ‰. The unmixed C-water, which penetrates into this Area from the north, is found at slightly greater depths than in Area V and is covered over by a mixture of C-water and E-water, as appears from Fig. 32. At stat. 1185 we find unmixed E-water with the salinity 34.94 ‰.

At a depth of ca. 800 metres the S-water makes its influence strongly felt, as is shown among other things by the low oxygen contents. We find low oxygen contents especially in the eastern part of the Area, but at less depth than in the western part. These low oxygen quantities may be due to a very slow movement of the CS-water in the eastern part of the Area.

From 1500 metres down to greater depths we find JB-water and in the greatest depths almost unmixed B-water. In the western part of the Area this water is rich in oxygen, ca. 80 %, whereas in the eastern part only 61 % is found at 1500 metres. Between 800 and 1500 metres there is a mixture of JB- and CS-water, the B- and S-waters being the chief constituents.

Area VII is bounded in the west by Area I, in the southwest by Area II and in the south-east by a line from Area II over towards Ireland.

Most of the stations in this Area are taken from the report of B. HELLAND-HANSEN and FRIDTJOF NANSEN on "The Eastern North Atlantic" (HELLAND-HANSEN and NANSEN 1926). These stations are noted as HN 4a, HN 5, HN 62, HN 61, HN 60, HN 59, HN 86, HN 87 and HN 88a. Further, there are two stations Th 60 and M 22/7 from Danish investigations with the "Thor" (J. N. NIELSEN 1907) and with the "Margrethe" (JACOBSEN 1916).

The stations are indicated with the above signs on the chart Fig. 63.

To give a survey of the water-movement in the Area considered and in the neighbouring areas the chart Fig. 36, is reproduced from the report of HELLAND-HANSEN and NANSEN. It shows the direction and strength of the current at a depth of 100 metres in relation to the depth of 2000 metres according to the dynamical calculations of these authors. In agreement with the topographical charts constructed by HELLAND-HANSEN and NANSEN for the Area represented in Fig. 33 the current picture for the depth of 100 metres also applies to greater depths, except that the current decreases greatly with the depth and is already at 600—800 metres of subordinate importance in comparison with the current in the uppermost layers.

The boundary lines between the areas as used in the present paper are entered on the chart.

Of the above-mentioned stations the TS diagrams for M 22/7, Th 60 and HN 60 have already been mentioned (p. 48—49). The material from the stations has been dealt with in a similar manner to that used for Area II and following areas; see Table 19 p. 64 and Fig. 33.

A consideration of the TS-diagrams in Fig. 33 shows, that the qualities of the water vary considerably within the Area. In its southern part the CS-water is prominent and at stat. HN 87 especially it occurs in various mixtures with salinities varying from 35.7 ‰ to 35.3 ‰ at depths from 75 to 600 metres. At the same station the CS-water from 600 down to 1000 metres is greatly mixed with B-water and JB-water. These hydrographical conditions are essentially the same as those found in the south-eastern part of Area I, though the salinity of the CS-water reaches somewhat higher values than in that area.

Fig. 36. Directions and velocities of the currents at about 100 m in relation to 2000 m. Reproduced after Bjorn Helland-Hansen and Fridtjof Nansen: The eastern North Atlantic (1926).

At stat. HN 86 the CS-water occurs with the salinity 36‰ at a depth of 75 metres, but in contrast to what is the case at stat. HN 87 we find JB-water from 400 to 1200 metres without any essential admixture of CS-water.

Lastly, more developed mixing conditions between the different kinds of water are found at stat. HN. 88a. Between 100 and 400 metres there is CS-water and below 400 metres a mixture of CS and JB-water, with which at depths about 1000 metres some M-water is probably mixed. This can scarcely

be imagined however to be the case at the stat. HN 87 and 86, so that stat. HN 88a is near the boundary of the distribution of the M-water. Its great specific gravity has the effect that it gradually becomes mixed with the water at great depths between the Atlantic Ridge and the continental shelf off the west coast of Europe.

In agreement with the picture given by HELLAND-HANSEN and NANSEN of the current conditions (see Fig. 36), we may consider that an inflow of water from the west into Area VII occurs almost where the above-mentioned stations are situated and that this water consists partly of CS and partly of JB-water. As the salinity of the CS-water, which enters Area VII, possesses somewhat higher values than were found at the stations in the south-eastern part of Area I, we may conclude further, that the water which penetrates into Area VII comes in part at any rate from latitudes further south than Area I. This is also indicated by the isobar diagram published by W. EKMAN (1923), which has been used in constructing the isobar chart Fig. 53. As previously mentioned, we may conclude that AB and CS-water with higher salinities than the J-water are mixed in Area I with the water of low salinity present in the Newfoundland region. This is not the case with the CS-water that penetrates into Area VII, especially that found at stat. HN 86.

As can be seen from the current chart of HELLAND-HANSEN and NANSEN, Fig. 36, a portion of the water which enters from the west into the southern part of Area VII bends off in a northerly direction almost following the line in which the stations HN 59 and HN 62 are situated. The TS diagrams show for these stations, that CS-water with essentially higher salinity than that of the J-water has disappeared. The probable explanation of this phenomenon is, that the surface-water from Area I is carried over into Area VII by the prevailing west winds and is partly mixed with, partly displaces the CS-water with higher salinity than that of the J-water.

Cooling in winter will also cause the CS-water to become colder and mixed with the underlying layers. This in conjunction with the successive mixings of the relatively little stable CS-water causes the latter to appear in Area VII with such a small difference in temperature and salinity as is the case. On the TS curves it is evident that the depths marked lie comparatively close together in the neighbourhood of the temperature and salinity of the J-water.

In deep water the CS-water is very prominent at stat. HN 59 down to about 1000 metres, though it is strongly mixed with JB-water. Below this depth presumably the water consists mainly of JB-water, even if the temperatures and salinities recorded deviate somewhat from the line JB.

At the stations farther to the north, HN 60, HN 61 and HN 62 the TS curve approximates more closely to the line JB, also for depths between 100 and 1000 metres, but this hardly means that the JB-water is more strongly represented than at stat. HN 59. It is due probably to the fact, that the M-water coming from the south makes its influence felt in depths about 1000 metres. This is specially noticeable at stat. HN 60 (see Fig. 21).

According to the current chart of HELLAND-HANSEN and NANSEN, Fig. 36 p. 67, the NNE-going water-movement bends off towards the NW almost at stat. HN 62 and in agreement with this we find similar TS diagrams at stat. HN 4a and HN 5 as at the previously mentioned stations. It has to be remarked however, that CS-water is strongly represented at Stat. HN 5 and shows but a small admixture of M-water.

It may also be concluded, that CS-water is strongly represented at stat. M 22/7 (see Fig. 21). The irregular form of the TS-curve is possibly due to some uncertainty in the observations, but the mixing conditions here (ca. 54° N., 25° W.) may probably be extremely variable. As mentioned on p. 59, a mixture of B-water with the surface-mixture characteristic of the Area I was the principal water found at the adjacent Stat. HN 6 from the surface down to ca. 800 metres.

With regard to the eastern part of Area VII north-west of Ireland, the TS-diagram for stat. Th 60 (see Fig. 21) shows that the water may be characterized as JB-water with a small admixture of M-

water. This is interesting, as we find here, just as at stat. HN 62, almost homogeneous water between 100 and 600 metres. As already mentioned (p. 49) it may be concluded, that the incoming J-water collects here to form a relatively thick layer.

With regard to the oxygen contents at the stations lying in Area VII it may be remarked, that from the surface down to a depth of 400 metres we find a fairly high percentage of oxygen (greater than 93 %), and that an oxygen minimum occurs at a depth of 800 metres with 74 %. This small amount of oxygen is due to the influence of the S-water.

In his recent paper GAARDER (1927) has given a survey of the amount of oxygen in this region of the Atlantic.

In their main features the hydrographical conditions in Area VII are characterized by the occurrence of a mixture of CS and JB-waters in depths from 100 metres down to about 1000 metres, and of JB-water in greater depths. In the eastern part of the Area there is an admixture of a considerable quantity of M-water in depths about 1000 metres. In the eastern part also we find a relatively uniform water-layer from 100 down to 600 metres consisting of J-water.

Area VIII about 45° N., 15°W., bounded towards the east by the European coast from south-west Ireland to the north-west point of Spain (see chart Fig. 63).

Of the stations lying in this Area two come from the present "Dana" Ekspedition, stat. 1103 and 1387, three Th 65, Th 69 and Th 70 from the Danish investigations with "Thor" (J. N. NIELSEN 1907), one station P 1 from the German investigations with "Planet" (W. BRENNECKE 1909), five stations D 1, D 2, D 3, D 4 and D 5 from the German Antarctic Expedition with the "Deutschland" 1911—12 (W. BRENNECKE 1921) and lastly, 14 stations from the report published by B. HELLAND-HANSEN and NANSEN on "The Eastern North Altantic" (HELLAND-HANSEN and NANSEN 1926). The last-named stations are noted as HN 6, HN 10, HN 11, HN 15, HN 58, HN 57, HN 56, HN 55, HN 44, HN 42, HN 41, HN 40, HN 38 and HN 37. All the stations mentioned are noted on the chart Fig. 63 by these signs and the available hydrographical material is represented in the usual manner in Fig. 34 p. 65 and by mean-values in Table 19 p. 64. The TS diagrams for stat. 1387 has already been dealt with p. 49.

According to the current chart of HELLAND-HANSEN and NANSEN, Fig. 36, and the dynamic chart of the same authors, we may expect that the uppermost layers in this Area will be characterized by the water coming from the west, which penetrates into the south-western part of Area VII. This water consists mainly of CS-water mixed with J-water. It will be seen from Fig. 34, that we find in Area VIII down to about 800 metres essentially the same kind of water as in the southern part of Area VII. According to the diagrams the J-water must be predominant in depths of 400 to 600 metres.

Taking all the stations together we find CS-water in Area VIII with salinities from ca. 35.2 to 36.0 ‰, but the conditions within the Area are not a little variable. CS-water with high salinities are most prominent in the south-western part of the Area.

For the uppermost 100 metres or thereabouts the TS curves show a vertical course, but with different positions for the different stations. This is due to heating from the atmosphere, as the uppermost 75 to 100 metres of the CS-water have become homogeneous owing to the winter cooling. In the eastern part of the Area, roughly east of 15° W. Long., the salinity of this homogeneous layer is equal to that of the J-water with S = 35.5 ‰. In the western part of the Area, on the other hand, the homogeneous surface layer is formed in the CS-water with considerably higher salinity than that of the J-water.

In the eastern part of the Area below the ca. 100 metres thick upper layer mentioned we find very nearly homogeneous water with the temperature and salinity of J-water down to 600—700 metres. This has already been referred to in connection with the TS diagram for stat. 1387 (p. 49). In the western part of the Area from 100 to 700 metres we find various water-mixtures, partly CS, partly JB-water and partly mixtures of these together and with M-water.

As the diagrams Fig. 34 show, there is a strong admixture of M-water in the whole Area VIII, which is recognizable from the fact that the TS curves for depths about 1000 metres and more follow in the main the line MB. The salinities of the MB-water at the different stations in the Area are however somewhat variable, on the whole greatest in the eastern part because the M-water in its north-going movement keeps mainly to this part.

Between 600—700 and ca. 1000 metres we find a mixture derived from MB-water and the mixture occurring in ca. 700 metres. The comparatively small amount of CS-water and JB-water with low salinity

Table 20.

Depth m	Area X			Area XI[1])					Area XII[1])					Area XIII[1])				
				I	II	I	II	I	I	II	I	II	I	I	II	I	II	I
	Temp. Mean	Salin. Mean	Oxyg. Mean	Temp. Mean	Temp. Mean	Salin. Mean	Salin. Mean	Oxyg. Mean	Temp. Mean	Temp. Mean	Salin. Mean	Salin. Mean	Oxyg. Mean	Temp. Mean	Temp. Mean	Salin. Mean	Salin. Mean	Oxyg. Mean
0....	22.76	36.99	101	22.75	18.96	36.70	36.50	94.6	23.87	21.64	36.30	35.90	97.5	25.15	26.52	35.86	35.47	97.7
25....	21.07	37.09	99	24.15	18.66	74	43	94.5	25.96	20.47	32	67	..	25.59	25.44	87	34	97.8
50....	20.36	36.95	100	22.24	18.48	90	48	92.4	23.61	17.24	18	83	96.3	23.18	18.08	36.08	51	93.3
75....	..	..	..	19.96	17.95	88	46	96.0	20.63	15.90	54	74	84.9	18.99	15.00	18	39	64.1
100....	19.44	36.90	100	18.72	17.53	74	47	87.6	18.33	15.17	38	70	62.1	16.67	14.05	35.67	32	55.2
125....	..	..	..	..	..	..	..	..	..	..	..	..	..	13.04	..	34	..	40.8
150....	..	..	..	17.61	..	36.55	..	77.2	15.60	..	36.00	..	46.2	13.35	..	43	..	42.6
200....	17.30	36.51	86	16.83	15.53	37	36.10	78.4	13.88	13.23	35.74	35.46	38.8	11.71	12.15	20	35.16	37.7
300....	..	..	..	14.70	..	03	..	67.0	12.06	..	45	..	30.1	10.38	..	03	..	30.2
400....	14.30	35.95	78	13.06	12.41	35.70	35.64	56.7	10.84	10.28	30	35.19	29.9	9.87	10.14	03	35.14	28.0
500....	..	..	..	11.72	..	61	..	60.0	9.59	..	17	34.58	27.4	8.80	..	34.94	..	25.2
600....	11.90	35.67	70	10.58	9.68	43	35.27	50.4	8.42	8.06	04	34.97	26.4	8.06	7.68	87	34.89	30.4
700....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
800....	10.14	35.54	62	8.14	7.43	35.18	35.03	36.2	6.66	6.39	34.88	34.81	35.5	6.32	6.15	34.78	34.80	35.4
900....	..	..	..	..	..	..	08	..	..	..	..	..	..	..	..	..	..	..
1000....	8.57	35.44	58	6.86	6.76	35.07	09	45.4	6.10	5.80	34.92	34.90	42.2	5.52	5.36	34.80	34.90	42.6
1200....	7.78	44	65	6.34	6.20	18	..	52.0	5.44	..	35.00	..	50.6	5.03	..	90	..	51.7
1500....	6.26	36	66	5.31	4.94	14	35.12	56.8	4.50	4.36	03	35.00	59.8	4.32	..	95	..	62.4
2000....	4.40	16	75	3.86	..	04	..	60.8	3.51	..	34.94	..	60.0	3.48	..	96	..	67.6
2500....	..	..	..	3.23	3.07	00	35.01	56.2	3.10	..	92	..	66.1	3.06	3.13	92	..	67.0
3000....	2.83	34.97	74	2.86	..	34.96	..	53.2	2.80	2.72	93	34.96	67.8	..	..	..	..	..
3500....	..	..	..	2.56	2.58	90	35.07	56.8	2.59	2.64	90	34.88	55.2	2.57	..	34.87	..	70.0
4000....	..	..	..	2.48	..	94	..	55.0	2.46	..	88	..	59.3	2.50	..	90	..	64.5
4500....	2.47	34.94	70	2.44	..	92	..	47.0	..	..	..	..	..	2.38	2.35	86	34.87	55.8
5000....	..	..	..	2.50	..	35.01	..	..	..	..	..	..	..	2.60	2.33	87	35.01	..

[1]) The area divided into part I and II, part II contains the stations near the coast of Africa and part I the remaining stations.

which may be brought into this Area has probably become mixed with MB-water and has likewise entered into this mixture between 600—700 and 1000 metres. This may be inferred from the fact, that the MB-water has a greater specific gravity than the other kinds of mixtures.

With regard to the oxygen contents in this Area it should be noted, that the oxygen percentage in the uppermost layers down to a depth of 400 metres is quite considerable — on an average for the different depth more than 91%. Then it decreases to a minimum in 1000 metres (71.2%) due to the M-water. At a depth of 2000 metres we find the oxygen maximum (84%) and here therefore the reneval with B-water may be considered to be at its greatest.

Area IX about the Azores.

In this Area we have the "Dana" stations 1369, 1370, 1373, 1376 and 1379, the stations D 7, D 8, D 9 and D 10 from the German Antarctic Expedition of 1911—12 (W. Brennecke 1921) and the station

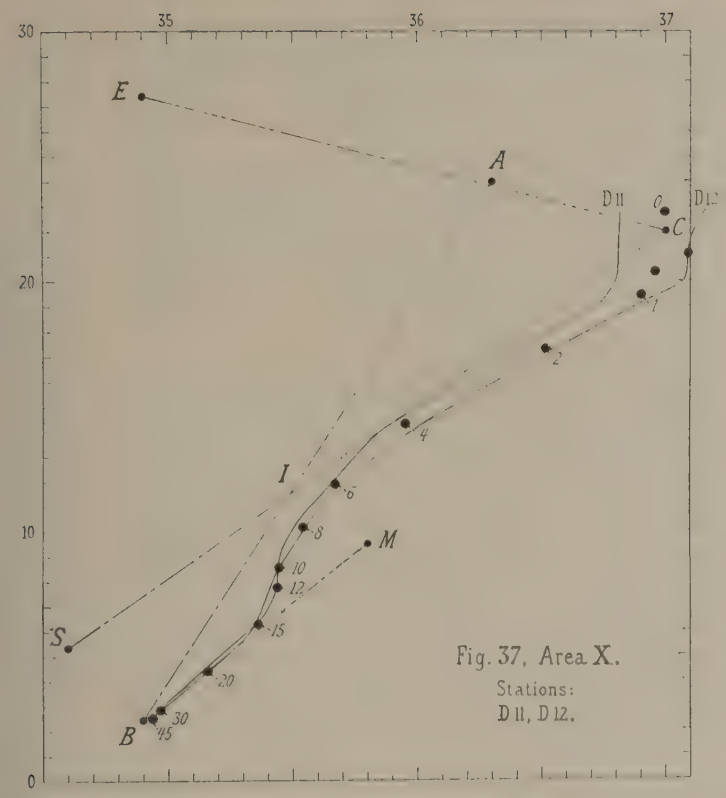

Fig. 37, Area X.
Stations:
D 11, D 12.

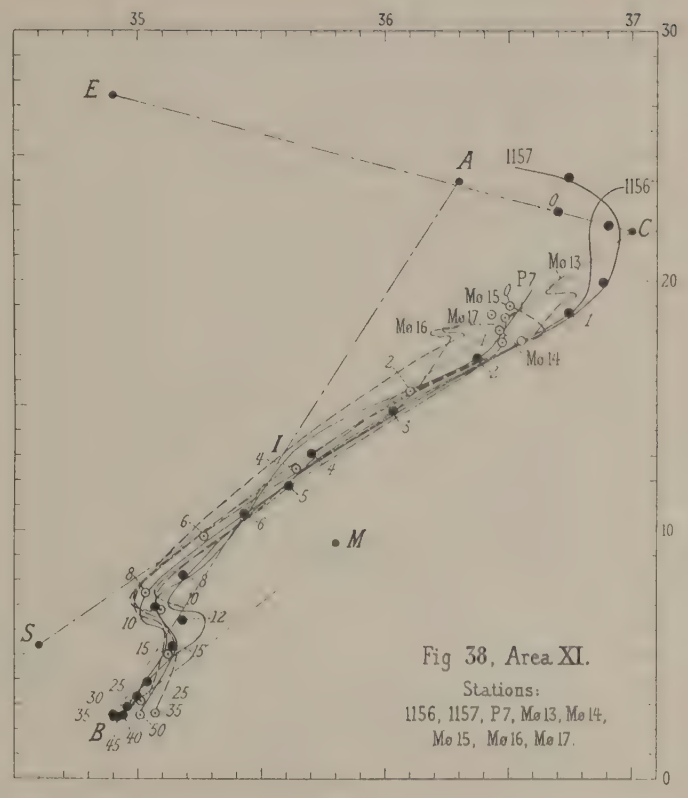

Fig. 38, Area XI.
Stations:
1156, 1157, P 7, Mø 13, Mø 14,
Mø 15, Mø 16, Mø 17.

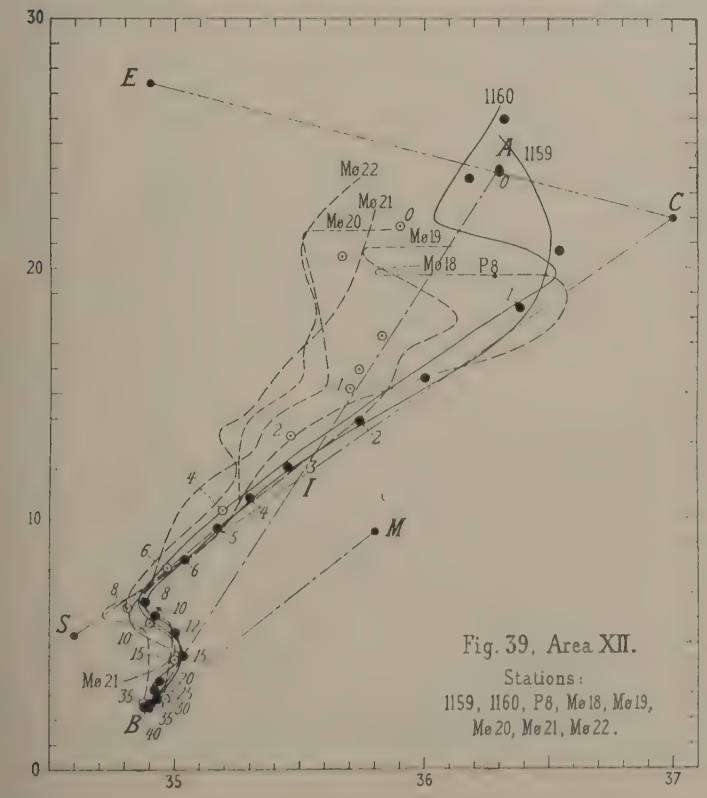

Fig. 39, Area XII.
Stations:
1159, 1160, P 8, Mø 18, Mø 19,
Mø 20, Mø 21, Mø 22.

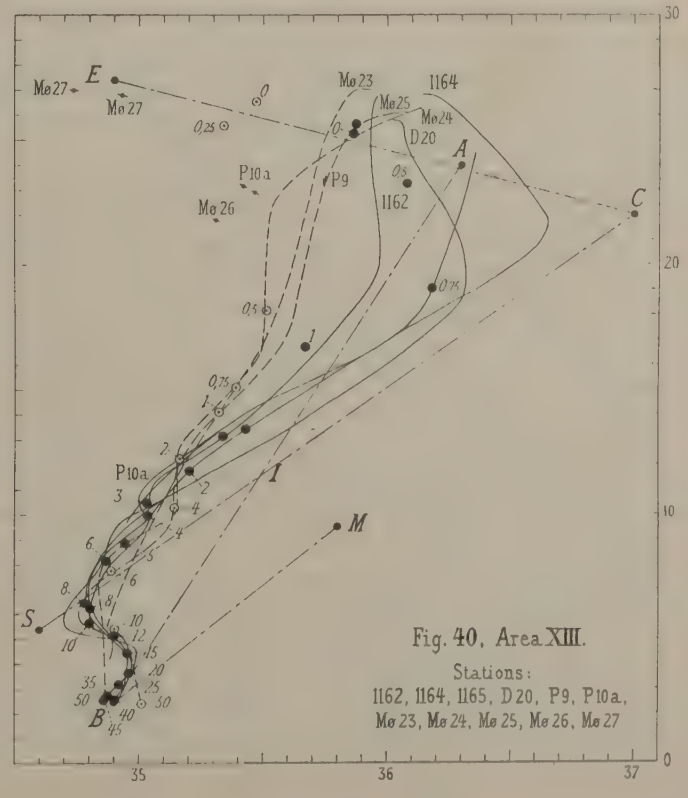

Fig. 40, Area XIII.
Stations:
1162, 1164, 1165, D 20, P 9, P 10 a,
Mø 23, Mø 24, Mø 25, Mø 26, Mø 27

HN 54 from HELLAND-HANSEN and NANSEN's report on "The Eastern North Atlantic" (HELLAND-HANSEN and NANSEN 1926). All the stations mentioned are noted on the chart Fig. 63 by the above signs and the hydrographical material is summarised in the usual manner in Table 19 p. 64 and Fig. 35 p. 65. Of the stations mentioned stat. 1369 has already been discussed (p. 35).

The diagrams from the different stations regarded as a whole display similar conditions to those shown in the diagrams for the Area VIII. Here also the curves for the uppermost 100 metres show an almost vertical course, due to the heating in summer of the homogeneous water formed by winter cooling. CS-water occurs from 100 to 600 metres with salinities from 36.1 or 36.2‰ down to that of the J-water (35.5‰) and thus has most resemblance to the CS-water occurring in the south-western part of Area VIII, but in Area IX it has considerably higher salinities than in Area VIII.

The influence of the M-water and consequent occurrence of MB-water are also similar in the two areas, but Area IX shows most resemblance to the north-eastern part of Area VIII in agreement with the fact, that the M-water in addition to spreading out in the region west of Gibraltar has a tendency to move northwards. It is a consequence of this, that the CS-water with salinities lower than those of the J-water is only found to a small extent in Area IX, the CS-water with lower salinity possibly present entering into the mixture, which is represented by the piece of the curve for depths from 600 to 1000 metres. MB-water with the greatest salinity occurs at stat. 1370, which is explained by the position of this station to the south of the Azores, see Fig. 58.

In Area IX the oxygen contents decrease more rapidly with the depth than in the previously mentioned Area VIII, the average value of saturation being 90.6% already at 200 metres where the water consists of CS-water with relatively high salinities. The oxygen minimum occurs at 1000 metres with 69.8% and is mainly due to the influence of the M-water. The increase in the quantity of oxygen with the depths presents the usual picture arising from the influence of the B-water.

Area X between the Canary Isles and 30° W. Long.

In this Area we have the two stations D 11 and D 12 from the German Antarctic Expedition of 1911—12 (W. BRENNECKE 1921). The position of the stations is noted in the chart Fig. 63 and the hydrographical material is given by mean values in Table 20 and by diagrams in Fig. 37.

The diagrams show, that the water from 100 down to 600 metres may be characterized as essentially CS-water, though the TS curve lies somewhat lower than the line CS, especially for the station D 12. This peculiarity may possibly be due to an admixture of water in depths from 100 to 600 metres which has risen up from greater depths on the coast of Africa (see Areas XI and XXIII). The CS-water occurs with varying composition, the salinities ranging from almost unmixed C-water (37‰) to J-water (35.5‰).

Between 600 and 1500 metres we find a water-mixture which is essentially different from the mixture in the corresponding depths in Area IX, the JB-water from the north-west being more conspicuous here whilst the influence of the M-water is less. Presumably some CS-water also occurs in this mixture. From 1500 metres to the bottom MB-water is found.

The CS-water occurring in Area X comes from more northern latitudes and has taken part in the cyclonic movement in the Sargasso Sea (see isobar chart Fig. 53). It is more subsaturated with oxygen than the CS-water in the previously discussed areas, but does not descend to the low oxygen values found in the Area XI which lies to the south-east of Area X, where CS-water from the south stagnates. The oxygen minimum in Area X is found at a depth of 1000 metres with 58% and probably arises chiefly from the stagnating M-water. The quantities of oxygen in deep water are also relatively low, signifying that the renewal of water there by means of incoming B-water proceeds at a relatively slow rate.

Area XI south-west of the Canary Isles, reaching to the African coast in the east.

In this Area lie the "Dana" stations 1156 and 1157, the station P 7 taken by the German "Planet" Expedition of 1906—07 (W. BRENNECKE 1909) and the stations Mõ 13, Mõ 14, Mõ 15, Mõ 16 and Mõ 17

taken by the German "Möve" Expedition of 1911 (G. Schott u. B. Schulz 1914). The position of the stations is noted on the chart Fig. 63. This area has been divided into two parts, namely the part near the African coast, where the stations taken by "Möve" are situated and the part further from the coast containing the other stations. In Tab. 20 p. 70 average values are given for both parts of the area and in Fig. 38 p. 71 the curves have been drawn as discontinuous lines for the stations taken by "Möve" and as fulldrawn lines for the other stations.

The mean values plotted in the diagram are given by the sign ○ for the stations taken by "Möve" and by ● for the other stations. As usual the depths are stated at most of the mean values plotted in the diagram and referring to the two sets of mean values two sets of depth indications are also found in the diagram.

Of the stations in this Area stat. 1156 has already been discussed (p. 41).

It will be seen from Fig. 38 p. 71 that the TS-curves for depths between 100 and 800 metres follow in the main the line CS for all stations in the Area and the water in this layer undoubtedly consists mainly of CS-water in almost all admixtures with salinities varying from roughly 35‰ to 37‰. Some deviation between the TS curves and the line CS is certainly present, especially in the lower depth, but it is not so pronounced for the "Möve"s stations as for the others. We may conclude, therefore, that essentially the same water-mixture occurs everywhere in the Area. On the other hand it will be seen from the diagrams, that the depths records showing the average values of the "Möve"s observations and those referring to the other stations are not found at the same place on the TS curves. The deviation is especially great for the smaller depths.

This difference in the position of the depth records is produced by the known ascending movement of the water at the African coast. The difference in the water at the same depth is also seen distinctly from the average values for the two sets of stations noted in Table 20.

Even if we may conclude however, that the water occurring in the whole Area at the depth interval mentioned is mainly CS-water, yet it is probable that this water is of different origins in the uppermost and lowermost layers. In the upper layer with salinities greater than those of the J-water, it comes at least in the main from more northerly latitudes (see isobar chart Fig. 53). The CS-water in the deeper layers with less salinity than that of the J-water may on the other hand rather be considered to have been formed on the southern side of the central region, where the C-water occurs, an admixture arising here between the C-water and the S-water advancing from the southern latitudes. The movement of the CS-water formed in this way may be considered to be very slow. This also applies, though to a less extent, to the CS-water in the upper layers. In the whole of the depth interval considered the percentage of oxygen is low. The minimum is found at a depth of 800 metres with 36.2%, which is lower than even the oxygen percentage of the S-water with 40%.

For the uppermost 100 metres the TS curves show an irregular course, which is due in part to the influence of the atmosphere, but the ascending water-movement at the African coast probably contributes. In this connection it may be remarked, that the oxygen percentage at the stations 1156 and 1157 show under-saturation at the surface, namely 88.8% and 95% respectively.

From 1500—2000 metres down to the greatest depths we find MB-water, but it has here low salinities only. This finds a natural explanation in the fact, that the M-water during its relatively slow movement southwards has sunk down to greater depths and become more strongly mixed with B-water than is the case with the M-water which has spread towards the north.

The low oxygen contents found in the MB-water of Area XI is due partly to the slow renewal of the B-water and partly to the stagnating condition of the M-water which has gradually lost more of its oxygen, already at a low percentage beforehand.

In the depth interval between from 800 to 1500 metres we find a mixed water formed from the overlying CS-water and the underlying MB-water.

Area XII round the Cape Verde Islands, bounded in the east by the coast of Africa.

In this Area lie the "Dana" stations 1159 and 1160, the station P 8 of the German "Planet" Expedition 1906—07 (W. Brennecke 1909) and the stations Mõ 18, Mõ 19, Mõ 20, Mõ 21 and Mõ 22 along the African coast of the German "Mõve" Ekspedition 1911 (G. Schott u. B. Schulz 1914).

The position of the stations is indicated on the chart Fig. 63. A representation of the hydrographical data for the Area is given in Table 20 p. 70 and Fig. 39 p. 71 in the same manner as was used for Area XI, the "Mõve" stations being distinguished from the others. Just as in Fig. 38 the discontinuous curves in Fig. 39 refer to the "Mõve" stations, the continuous lines to the others. Also the mean values for the two sets of stations are marked as in Fig. 38. Of the stations noted stat. 1159 has already been discussed (p. 41).

Consideration of the diagrams Fig. 39 shows, that there is far less agreement between the TS curves for the "Mõve" stations and the curves for the western part of the Area than was the case in the corresponding parts of Area XI. The explanation must be, that the ascending water as it reaches up to the surface becomes greatly heated and thereafter mixed with the underlying water down to a depth of ca. 300 metres. This process of heating and mixing takes place in the eastern part of Area XII, but a part of the mixed water of the kind mentioned occurring in the Area may rather be considered to have been formed in more northern latitudes along the coast of Africa, whence it has been carried by south-going currents into Area XII. One might suppose, that the stability produced by heating would counteract the presumed mixing to such an extent, that it could not become so great as is shown by the course of the curves, but one must take into consideration that great mixing forces exist along the continental shelf owing to the wave movement, probably also vertical vortex movements and lastly, it has to be remembered, that the currents present in Area XII are probably weak, except in the uppermost layers. It should be remarked that it is the TS curves for the stations nearest the coast, Mõ 20, Mõ 21 and Mõ 22, which especially differ from the curves for the western part of the Area, whilst the curve for Mõ 19 agrees more with the latter.

For the western part of the Area the TS curves run very closely to the line CS for depths from 100 to 800 metres and on the whole the intermediate water-layer in these depths may be regarded as CS-water, even if the conditions produced by the ascending water-movement along the African coast also make their influence felt in this part of the Area, especially in the uppermost layers. Just as in Area XI the CS-water of Area XII occurs in various mixtures, but it must be remarked that the depth where the same kind of CS-water occurs, is considerably less in XII than in XI. This appears clearly from Table 20. For example, CS-water with the salinity 35.5 occurs at

stations	1156	1157	1159	1160
at depths (m.) of	ca. 600	ca. 550	ca. 300	ca. 230
with the oxygen contents	64 %	46 %	27 %	30 %

An ascending movement of the water from the deeper layers thus takes place at the Cape Verde Islands. This ascent is presumably a local phenomenon produced by the bank on which the Cape Verde Islands are situated; to this may be added the weak nature of the resultant currents in the depths considered.

As mentioned, the oxygen contents of Area XII in depths about 300 metres are unusually low, even lower than in the but little mixed S-water in 800 metres. From this we may conclude, that the CS-water is but slowly renewed at the Cape Verde Islands. Possibly the ascending movement along the African coast and the mixing processes connected therewith are chiefly responsible for the renewal.

The uppermost layers of the CS-water may be considered to have come from the north, whereas in depths of about 800 metres the incoming water consists of but little mixed S-water. There still seems to be a considerable admixture of M-water in the greatest depths in this Area, but otherwise the water

from 1500 metres down to the greatest depths consists of JB-water, which owing to its low oxygen contents may be considered to be but slowly renewed. Between 800 and 1500 metres we find a mixture of CS and JB-waters.

Area XIII extends from the coast of Africa south of the Cape Verde Islands to ca. 50° W. Long. It is bounded in the north by the Areas XII, V and VI and in the south by a line running east to west about 10° N. Lat. (see chart Fig. 63).

In this Area we have the "Dana" stations 1162, 1164 and 1165, D 20 from the German Antarctic Expedition 1911—12 (W. Brennecke 1921), P 9 and P 10a from the German "Planet" Expedition 1906—07 (W. Brennecke 1909) and the stations Mö 23, Mö 24, Mö 25, Mö 26 and Mö 27 from the German "Möve" Expedition 1911 (G. Schott u. B. Schultz 1914). The position of the station is given in the chart Fig. 63. The representation of the hydrographical data for the Area is given in Table 20 p. 70 and Fig. 40 p. 71 in analogous manner to the procedure in the preceding areas, the "Möve" stations being dealt with separately, see p. 73 and p. 74. Of the stations noted stat. 1162 has already been discussed (p. 42).

For this Area also the "Möve" stations (represented by the discontinous lines in Fig. 40) take up a special position due to the fact, that the water arising in more northern latitudes along the African coast has moved towards the south. The surface layer itself has become heated during this movement to similar temperatures (ca. 26°) as are found in the other part of the Area, but comparatively cold water (ca. 18°) occurs at 50 metres especially. The TS diagrams for the "Möve" stations have the same appearance as those for Area XII, and we may thus conclude, that here also the heated CS-water from deeper down has mixed with the remaining CS-water, possibly to depths about 300—400 metres.

What has been said for the "Möve" stations applies also in general to the remaining stations situated in the eastern part of the Area up to and including stat. 1162, but as already noted in dealing with the TS diagrams for stat. 1162 (p. 42) we have a special feature here, possibly also applying to the "Möve" stations, in that a mixed water formed south of the equator presumably enters the Area in similar manner to the CS-water north of the equator. This mixed water has been mentioned p. 42 and its TS diagram is shown in Fig. 19. Owing to the admixture of this water the TS curves for depths down to ca. 300 metres lie higher than the line CS even in the western part of Area XIII. The oxygen contents in the water coming from the south are but low, ca. 40 %, and this without doubt contributes to the low amount of oxygen in relatively small depths. It is also of importance in this connection, that the stability conditions in the uppermost layers are specially great, the E-water from the Equatorial Current making its influence felt on the surface.

According to definition the S-water occurs almost unmixed at a depth of ca. 800 metres but with slightly lower percentage of oxygen than that of S-water. Between ca. 500 and 800 metres we find CS-water and between this and the previously mentioned mixture in less than 300 metres we have a mixture of the latter and CS-water. The oxygen contents are everywhere very low in the depths mentioned, indicating that the water renewal proceeds very slowly. The CS-water coming from the north, which forms the overlying layer on the almost unmixed S-water, is carried but slowly away after mixing with the water of the Equatorial Current.

In the greatest depths we find JB-water consisting mainly of B-water, and between 800 and ca. 1,500 metres a mixture of this and CS-water. The oxygen contents in the JB-water in depths about 2,000 metres are relatively high, 68 %, so that, one may assume, the renewal of the water at this depth takes place fairly quickly. On the other hand, the oxygen contents of the unmixed B-water in the greatest depths are distinctly smaller, 55.8 % at stat. 1164 at a depth of 4,500 metres. Presumably the Atlantic ridge forms a barrier to the renewal of the B-water from the north at these depths whilst Antarctic bottom water is penetrating from the south (see p. 22).

Area XIV is situated to the east of the Caribbean Sea and reaches in the south to the coast of Guiana.

In this Area we have the "Dana" stations 1177, 1178, 1179, 1181 and 1182 (see chart Fig. 63). The data are used for Table 21 and Fig. 41. Of the stations mentioned the stat. 1182 has already been discussed (p. 44).

Table 21.

Depth m	Area XIV			Area XV			Area XVI			Area XVII		
	Temp. Mean	Salin. Mean	Oxyg. Mean	Temp. Mean	Salin. Mean	Oxyg. Mean	Temp. Mean	Salin. Mean	Oxyg. Mean	Temp. Mean	Salin. Mean	Oxyg. Mean
0.....	27.59	34.85	97.4	27.09	34.44	98.7	26.18	35.46	97.8	26.05	35.59	97.2
25.....	27.67	35.14	97.3	26.90	78	97.4	26.13	47	97.7	25.95	70	96.2
50.....	27.27	36.19	101.9	26.54	35.66	95.7	26.13	75	97.9	26.12	76	96.0
75.....	25.30	57	95.3	24.76	36.47	90.2	25.60	36.10	97.0	25.87	95	93.5
100.....	23.42	71	82.9	22.14	76	76.7	24.59	74	93.4	25.03	36.27	86.5
125.....	20.27	54	66.3	21.39	79	74.2	23.34	92	85.7	..	..	..
150.....	18.32	31	61.8	18.38	44	64.3	22.05	94	83.4	22.80	36.56	75.6
200.....	15.10	35.91	56.4	15.77	08	60.5	19.85	73	76.2	19.67	55	67.0
300.....	10.78	18	45.5	11.50	35.32	42.2	16.76	29	73.7	15.83	08	61.4
400.....	8.59	34.87	42.4	9.44	04	42.8	14.50	35.90	61.8	13.16	35.65	55.4
500.....	8.14	82	41.1	7.84	34.83	41.4	11.93	46	50.2	10.76	29	47.5
600.....	7.20	74	40.8	6.68	71	42.2	9.44	09	44.8	8.70	03	44.4
700.....	..	..	..	..	..	..	7.92	34.90	43.9	..	..	..
800.....	5.79	34.66	42.7	5.58	34.73	47.6	6.65	82	44.7	6.35	34.81	46.5
900.....	..	..	..	..	..	..	..	..	..	..	..	..
1000.....	5.23	34.77	48.1	4.74	34.88	56.2	5.36	34.90	55.8	4.98	34.89	57.4
1200.....	4.92	91	59.8	4.33	92	60.8	4.50	93	61.8	4.49	95	63.9
1500.....	4.30	35.00	73.0	4.16	94	63.4	4.17	96	67.2	4.22	95	67.1
2000.....	3.61	34.98	76.5	4.10	93	63.8	3.89	96	71.2	4.09	98	71.0
2500.....	3.05	97	76.8	4.14	94	62.1	3.90	96	72.7	4.08	98	68.0
3000.....	..	..	..	4.16	93	64.1	3.89	96	70.5	4.12	96	62.6
3500.....	2.42	34.91	73.3	..	..	..	4.00	96	70.3	4.16	98	66.4
4000.....	2.37	91	68.5	..	..	..	4.06	96	67.1	..	..	..
4500.....	2.30	91	74.8	..	..	..	..	..	..	..	..	..

Consideration of Fig. 41 shows, that the TS curves for depths from 100—150 down to 800 metres follow the line CS. Yet they lie on the whole slightly higher and this applies in all curves to the parts which represent the low temperatures and salinities in the depth interval considered. This is due to the previously mentioned water (p. 42), which comes from the region south of the equator and is formed, like the CS-water, from the salt surface water occurring south of the equator and the intermediate, but little salt water in depths of ca. 800 metres coming from the south. It is the last especially which differs from the corresponding intermediate water north of the equator. In agreement with this the TS curves deviate from the CS line specially for the low salinities.

With regard to the position of this part of the TS curves in relation to the CS line, there is some difference at the various stations, the curves for the western part being closer approximations to the line CS than those for the eastern part. This comes from the fact, that the mixed water coming from regions south of the equator has most influence in the eastern part of Area XIV, whilst more CS-water from northern latitudes is brought into the western part.

Another characteristic difference between the stations in the eastern and western parts of the Area is found in the CS-water with high temperature and salinity which occurs nearer the surface in the eastern than in the western part.

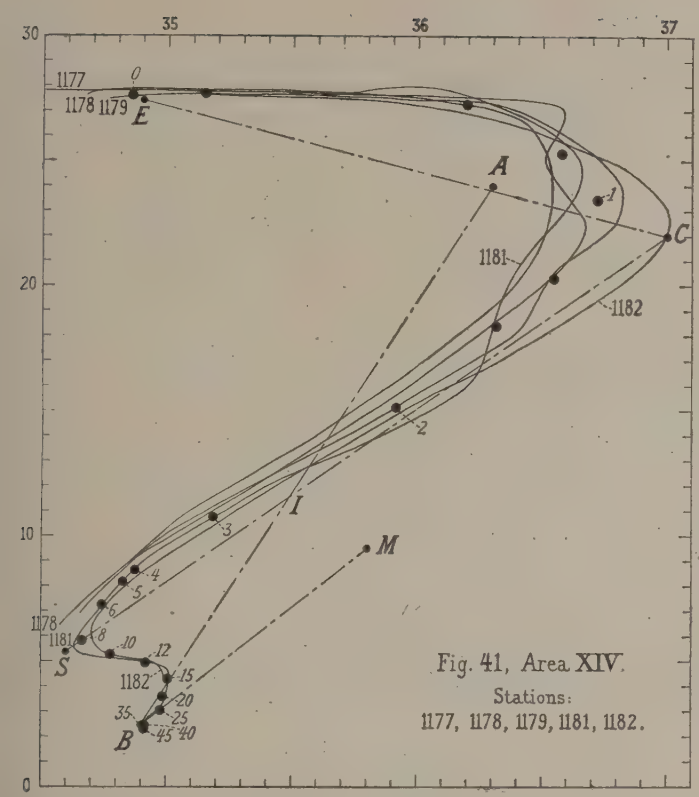

Fig. 41, Area XIV.
Stations:
1177, 1178, 1179, 1181, 1182.

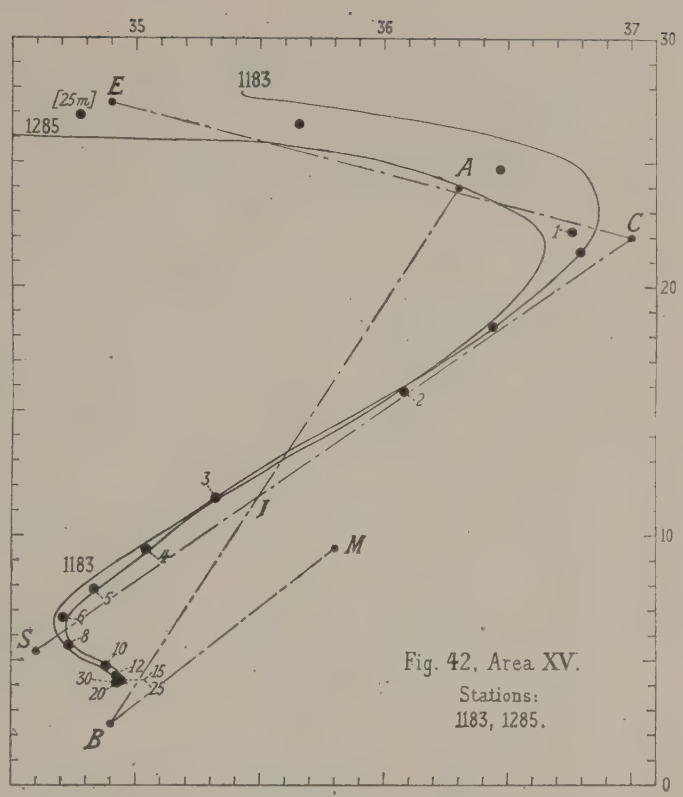

Fig. 42, Area XV.
Stations:
1183, 1285.

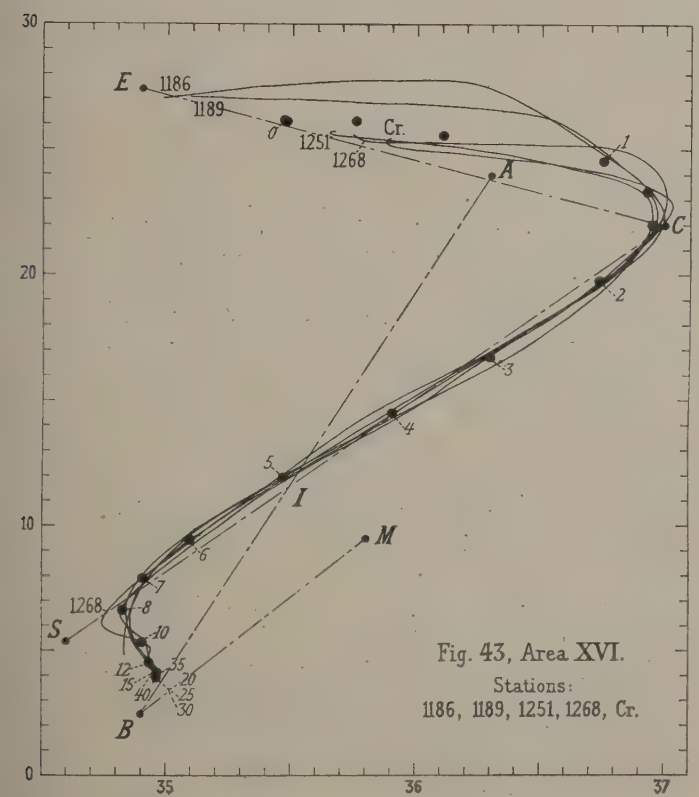

Fig. 43, Area XVI.
Stations:
1186, 1189, 1251, 1268, Cr.

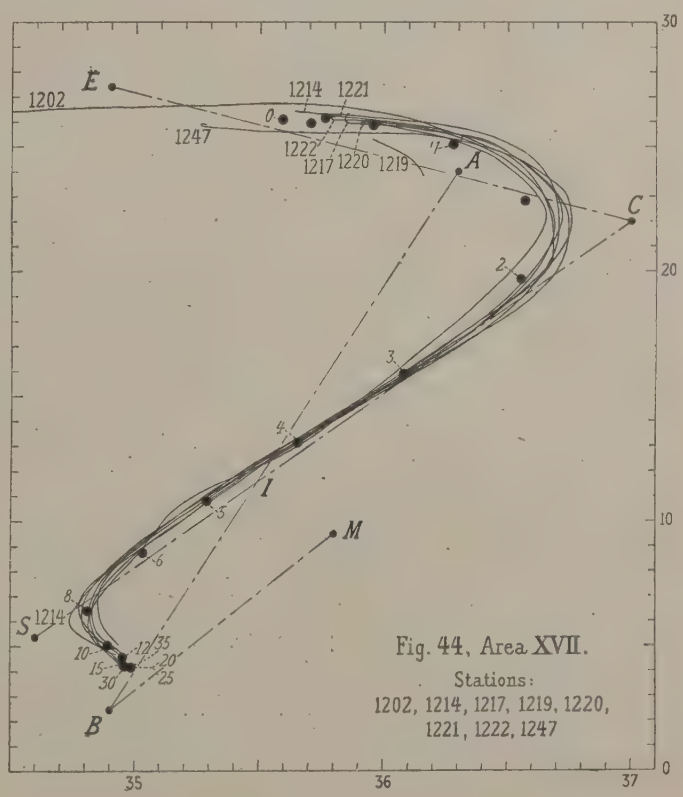

Fig. 44, Area XVII.
Stations:
1202, 1214, 1217, 1219, 1220,
1221, 1222, 1247

The oxygen contents in the water between 150 and 800 metres vary from ca. 60 % to ca. 40 % and remain almost the same for the same salinity. For the same depth, e. g. 200 metres, it is thus considerably lower in the eastern than in the western part of the Area. At a depth of 600 metres however we find a but little marked minimum of 40.8 %. By comparison with the oxygen in the CS-water of the more northernly Area VI, from which the inflow of CS-water into Area XIV may be considered to take place (see isobar chart Fig. 53), the oxygen contents in the Area XIV are quite low. But this is hardly due so much to the consumption of oxygen during the south-going movement of the water as to the addition of the mixed water, which is analogous to the CS-water, formed south of the equator. As previously mentioned, this water is poor in oxygen.

The E-water brought by the Equatorial Current is strongly in evidence from the surface down to 100—150 metres; on the surface we have essentially unmixed E-water and below this the various compounds of EC-water. The mixture however has clearly been heated from the atmosphere.

At a depth of 800 metres almost unmixed S-water occurs with oxygen contents 42.7 %; from 1,500 metres down to the greatest depths JB-water, which mainly consists of B-water. An oxygen maximum (76.8 %) is found in this water at a depth of 2,500 metres. Between 800 and 1,500 metres there is a mixture of S-water with a small addition of C-water and B-water with a small addition of J-water.

Area XV lies round the Caribbean Islands.

It embraces the two "Dana" stations 1183 and 1285, situated in the Caribbean Sea west respectively of St. Lucia and Martinique (see the chart Fig. 63). Stat. 1183 was taken on 24 Nov. 1921 and stat. 1285 on 7 April 1922. The data for the stations are shown by their means in Table 21 p. 76 and by diagrams in Fig. 42 p. 77.

Although these stations lie in the Caribbean Sea, the passages between the islands mentioned and between Martinique and Dominica farther to the north offer good possibilities for the levelling out of differences in the temperature, salinity and oxygen contents down to the depths between 1,000 and 1,500 metres found in the passages. In reality the TS diagrams for the two stations show fairly good agreement with the TS diagram for stat. 1182 in the western part of Area XIV for depths down to 1,500 metres. This holds good especially for stat. 1183 and 1182; for the latter the observations go down just to 1,500 metres.

On the other hand, the water in greater depths than 1,500 metres shows a distinct difference from that in the western part of Area XIV, as can be seen from a comparison between stat. 1183 and 1181. In the deepest water outside the Caribbean Islands we find unmixed B-water and above this up to ca. 1,500 metres JB-water with relatively rich oxygen contents, which reach a maximum of 76.8 % at depths of 2,500 metres. In depths of 2,000 metres and more within the islands we find homogeneous JB-water, which shows adiabatic rise of temperature with the depth and a smaller, but almost constant amount of oxygen ca. 63 %. These conditions have been already discussed (p. 46).

As shown by the isobar chart Fig. 53, an inflow of water occurs through the passages in the row of Islands, partly from the east, partly from the north-east, and the difference between the TS curve and the line CS in the diagram Fig. 42 shows, that a part of the mixed water, which is formed south of the equator in similar fashion to the CS-water, accompanies the inflowing water into the Caribbean Sea. As will be seen presently, this mixed water can be traced practically everywhere in the Caribbean Sea, whereas it is not found at the stations lying in the adjacent Area VI.

Area XVI comprises the most eastern part of the Caribbean Sea.

Observations have only been made in the northern part of this Area by the "Dana" Expedition. Of the stations 1251 lies south-west of Porto Rico at a distance of ca. 15 miles, stat. 1268 south-east of Porto Rico at a distance of ca. 70 miles, stat. 1186 and 1189 between St. Croix and St. Thomas, and one station west of St. Croix close to the island at which repeated series of observations were made.

The position of the stations is indicated on the chart Fig. 63 and the results of the observations are given in Table 21 p. 76 and Fig. 43 p. 77 the station just to the west of St. Croix being indicated in the figure by Cr. For this station both in the Table and the graph only the mean values of all the observations have been given. These observations have already been discussed (p. 16) and an extract has been shown in Table 4. Similarly, stat. 1268 has also been previously mentioned (p. 45) in discussing the selected TS diagrams.

It will be seen from the diagram Fig. 43, that the hydrographical conditions in Area XVI closely resemble those in Area XV round the Caribbean Islands. Yet a difference is seen in the part of the TS curves which represents mainly CS-water and which deviates less from the line CS than was the case for the Area XV. This indicates that CS-water from Area VI north of the Caribbean Sea is carried down into the present Area, especially through the Anegada passage.

In the uppermost layers the influence of the water coming from the north is shown by the fact, that the intermediate salinity maximum at a depth of 125—150 metres attains to a somewhat greater value (ca. 37 $^0/_{00}$) than was the case in Area XV.

For depths greater than 1,500 metres a difference is noticeable between the waters lying between St. Croix and St. Thomas (st. 1186 and 1189) and the place where the stations 1251 and 1268 were taken. For the former the temperature at a depth of 2,000 metres is 3,71 ° and the oxygen contents 75 %, whereas for 1251 and 1268 the temperature is 4.07° and the oxygen contents ca. 67 %. The reason for this difference between the two places is obviously to be sought for in the difference in the communications with the open Atlantic. At both places there is an adiabatic rise of temperature from 2,000 to 4,000 metres of respectively 3.89° — 3.72° = 0.17° and 4.22° — 4.06° = 0.16°.

Area XVII embraces the western part of the Caribbean Sea, including the Yucatan Channel.

In this Area we have the "Dana" stations 1202, 1214, 1217, 1247, 1219, 1220, 1221 and 1222 (see chart Fig. 63): The results of the observations are in the usual fashion given in Table 21 p. 76 and Fig. 44 p. 77. Of the stations mentioned st. 1214 has already been discussed (p. 45).

The hydrographical conditions in Area XVII are in the main just the same as in the more easterly areas XV and XVI, but with a few characteristic deviations. Thus, the surface salinity is on the whole higher in the western than in the eastern part of the Caribbean Sea, especially when stat. 1202 at the mouth of the Panama Canal is left out of consideration. This is due to the E-water of the surface becoming mixed during its west-going movement with the underlying salt water. In contrast to this, the intermediate salinity maximum has obtained a smaller value 36.6—36.7 $^0/_{00}$ through the mixing of the upper and under layer; in the north-eastern part of the Caribbean Sea its salinity was 37 $^0/_{00}$.

For depths from ca. 200 down to 800 metres the TS curves follow in the main the line CS, but at a depth of 600 metres we still find the characteristic deviation, which as in the previous areas shows the infusion of the mixed water coming from south of the equator and formed there in a similar manner to the CS-water.

Comparing the two deepest stations 1214 and 1217 of Area XVII together we see, that the temperature and salinity at depths greater than 1,500 metres are essentially the same and that the temperature from 2,000 to 2,500 metres displays the earlier mentioned adiabatic increase with the depth. On the other hand, the oxygen contents at depths greater than 1,500 metres are considerably higher at the more northerly station 1217 than at 1214. The renewal of the water near the bottom in the Caribbean Sea thus presumably proceeds comparatively slowly with the inflow of the intermediate water from without through the various passages, though only water down to ca. 1,500 metres deep penetrates from the Atlantic into the Caribbean Sea.

At a depth of 800 metres we find the intermediate salinity minimum due to the but little mixed S-water entering in from the Atlantic. During the westgoing movement in the Caribbean Sea however

some mixing of the layer at 800 metres takes place with overlying and underlying water, so that the salinity of the intermediate minimum is somewhat higher in the Yucatan Channel than in the remaining part of the Area.

At a somewhat lower depth than that of the salinity minimum (ca. 800 metres) we find the oxygen minimum and similar to the salinity the oxygen in the minimum is on the whole highest in the Yucatan Channel, without rising however appreciably above 45 %. Owing to the strong currents, especially in the Yucatan Channel, the isotherms and isohalines assume an oblique position, as described previously.

Table 22.

Depth m	Area XVIII			Area XX		
	Temp. Mean	Sal. Mean	Oxyg. Mean	Temp. Mean	Sal. Mean	Oxyg. Mean
0.....	25.54	35.93	96.3	22.79	36.53	100.9
25.....	25.34	92	..	22.15	61	101.5
50.....	25.24	98	96.8	21.55	61	101.1
75.....	25.29	36.20	93.1	21.29	62	99.8
100.....	24.92	45	94.9	21.07	62	98.2
125.....	..	..	..	19.58	60	96.9
150.....	23.14	36.82	83.6	20.17	61	93.8
200.....	21.08	83	77.0	19.44	59	88.6
300.....	17.32	37	78.4	17.90	45	84.4
400.....	15.74	12	70.8	16.95	31	81.1
500.....	13.76	35.84	61.2	15.66	10	75.1
600.....	11.58	50	51.2	14.00	35.85	68.3
700.....	..	..	..	12.62	64	64.3
800.....	8.10	35.08	48.5	10.15	31	54.7
900.....	..	..	..	9.43	22	54.8
1000.....	5.66	34.96	57.8	6.80	05	59.2
1200.....	4.74	35.01	68.7	5.18	03	73.0
1500.....	4.16	34.99	77.4	4.25	01	81.1
2000.....	3.82	99	79.8	3.59	34.97	82.5
2500.....	3.31	94	80.9	3.24	97	80.1
3000.....	2.95	94	80.0	2.90	94	78.6
3500.....	..	..	..	2.62	92	77.5
4000.....	..	..	..	2.42	90	79.6
4500.....	..	..	..	2.31	87	79.7
5000.....	..	..	..	2.26	87	78.3
6000.....	..	..	..	2.14	86	77.3

Area XVIII embraces the waters between Cuba and Haiti.

In this Area we have the two "Dana" stations 1244 and 1245, the former outside the latter inside the threshold of the Windward Passage. The results of the observations are reproduced in the usual manner in Table 22 and Fig. 45.

A comparison of the two stations shows that the surface salinity is less inside the passage than outside, due to the greater influence of the Equatorial Current inside the row of islands. Further, the maximum salinity at a depth of ca. 150 metres is greatest at the station lying outside the passage owing to the direct inflow of C-water from the north-east.

Otherwise the TS diagrams for the two stations are almost the same for depths down to 1,500 metres. At greater depths the stat. 1244 outside the passage shows high oxygen quantities, ca. 81 %, whereas at stat. 1245 with a total depth of only 2,002 metres the water at 1,950 metres is the characteristic deep water of the Caribbean Sea with less oxygen than outside in depths greater than 1,000 metres.

For the depths from 1,500 to 3,000 metres the TS diagrams for the two stations have the same appearance as the TS diagrams for the stations in the large Area XX lying to the north, and especially the but little prominent salinity minimum at a depth of ca. 1,000 metres resembles that at the stat. 1319 lying E. N. E. of the Area XVIII, which stands in contrast to the much more marked salinity minimum within the Caribbean Sea. The water at this depth has mainly a movement inwards through the Windward Passage (cf. p. 14).

Area XIX embraces the "Dana" stations lying north of the west point of Cuba and in the Florida Current, 1224, 1225, 1226, 1227, 1228, 1229, 1231, 1232, 1233, 1234, 1235, 1236 and 1237 (see chart. Fig. 63). Of these stat. 1227 has already been mentioned (p. 45) in discussing the special TS diagrams and the hydrographical conditions in the waters considered here have also been previously referred to in general p. 10.

For the purpose of the present treatment of the hydrographical conditions in Area XIX the data

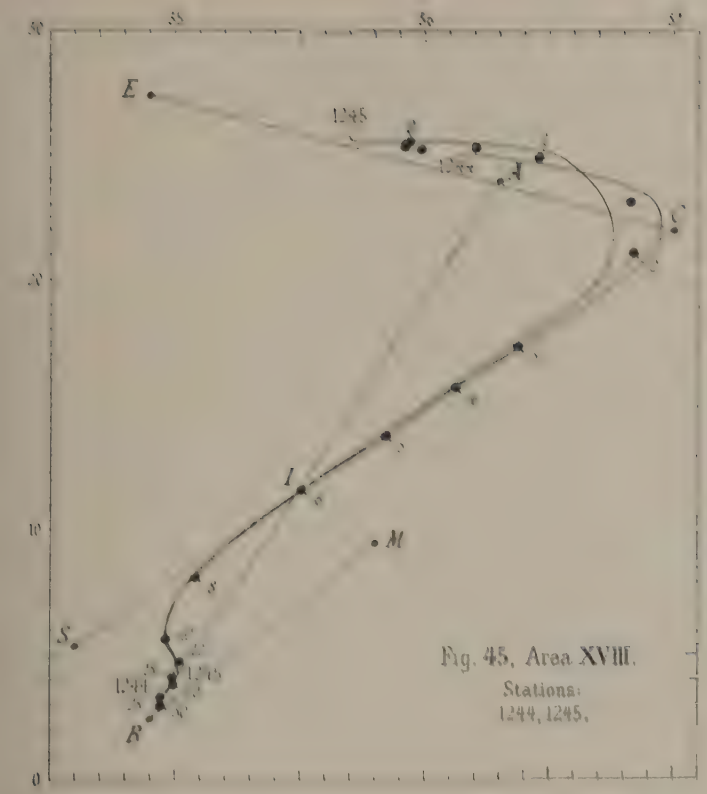

Fig. 45, Area XVIII.
Stations:
1244, 1245.

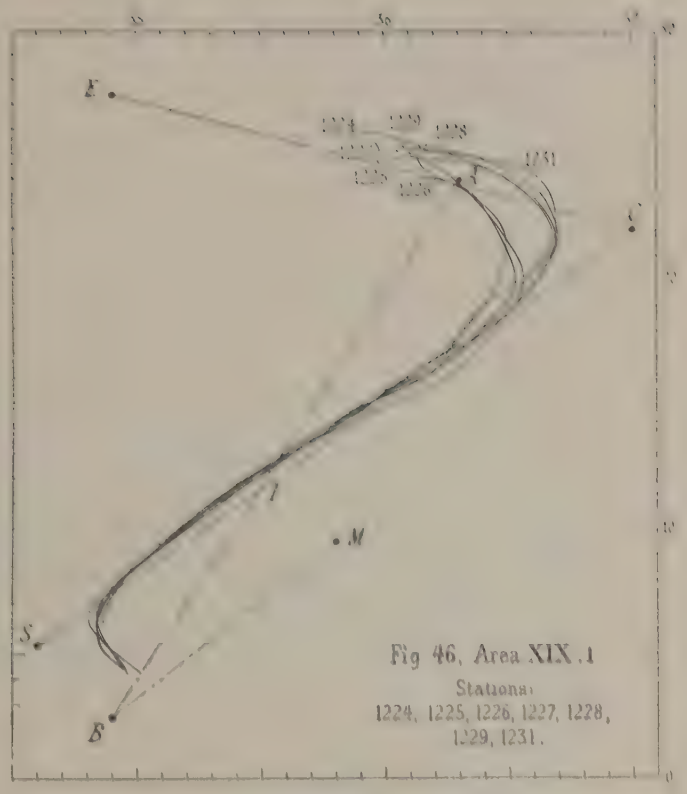

Fig 46, Area XIX 1
Stations:
1224, 1225, 1226, 1227, 1228,
1229, 1231.

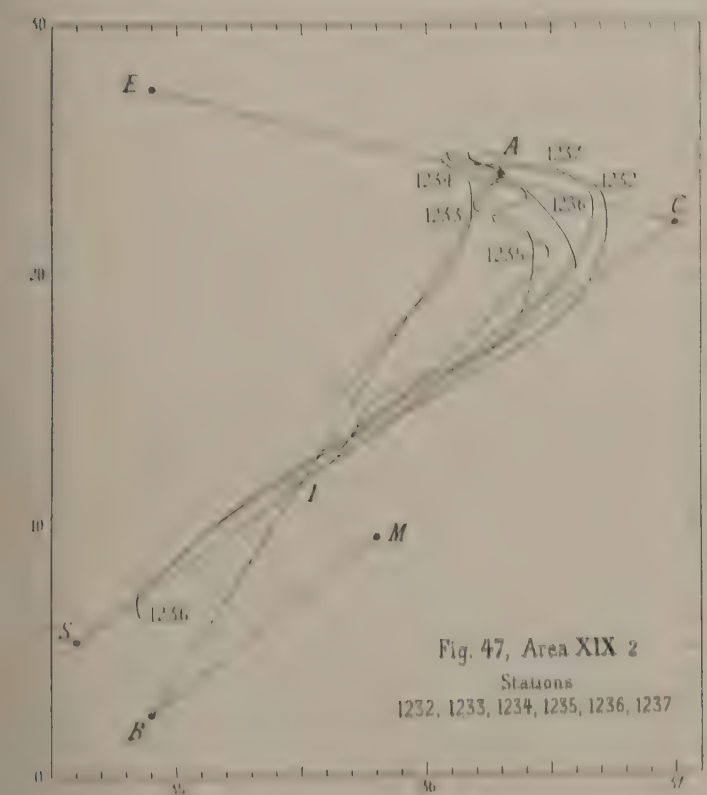

Fig. 47, Area XIX 2
Stations
1232, 1233, 1234, 1235, 1236, 1237

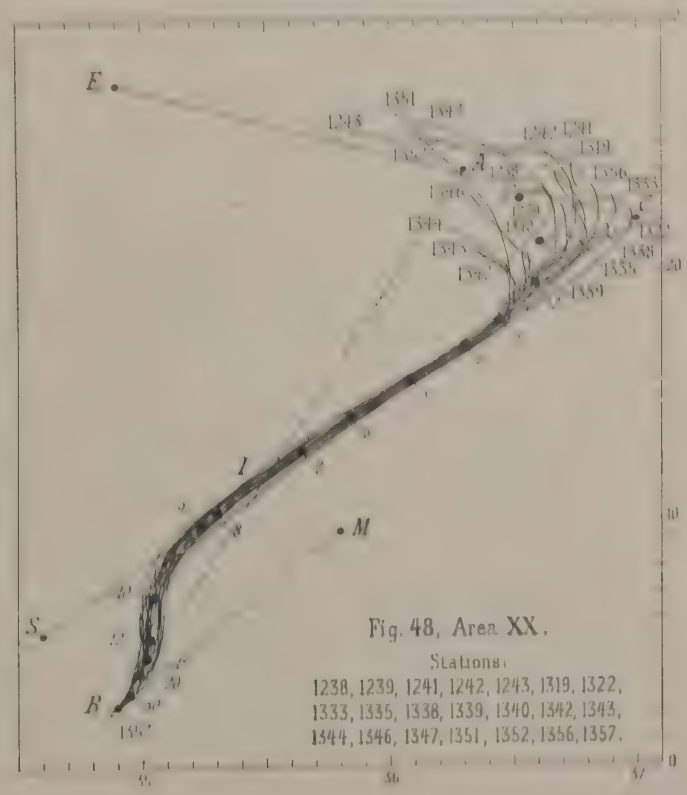

Fig. 48, Area XX.
Stations:
1238, 1239, 1241, 1242, 1243, 1319, 1322,
1333, 1335, 1338, 1339, 1340, 1342, 1343,
1344, 1346, 1347, 1351, 1352, 1356, 1357.

have been recorded in the Tables 23 and 24 below and represented in Figs. 46 and 47. Of these the Table 24 and Fig. 47 deal with the stations in the Florida Straits at the Bemini Isl., Table 23 and Fig. 46 the remaining stations 1224—1231. As seen from Fig. 46 the latter group of stations can naturally be divided into two groups, 1225, 1226 and 1227 in the first, 1224, 1228, 1229 and 1231 in the second.

The reason for the relatively great differences apparent within the Area XIX is obviously connected with the strong currents found in these waters. Isotherms and isohalines have a distinctly oblique position

Table 23. **Area XIX. 1.**

Depth m	Temperature							Salinity							Oxygen						
	1225	1226	1227	1224	1228	1229	1231	1225	1226	1227	1224	1228	1229	1231	1225	1226	1227	1224	1228	1229	1231
0	24.81	24.05	25.35	25.78	25.41	25.10	25.39	36.15	36.17	35.99	35.90	36.15	36.08	36.17	98.0	98.2	97.9	98.1	98.1	97.1	97.3
25	24.76	24.06	25.05	25.61	25.13	25.14	25.25	15	15	36.00	88	15	06	18	96.9	96.9	98.4	98.1	96.7	..	97.9
50	24.76	23.86	24.75	25.73	25.08	25.23	25.24	15	27	35.99	88	15	09	18	96.7	94.1	97.4	96.5	97.3	96.7	98.1
75	24.76	23.54	24.85	25.45	25.07	25.26	25.24	15	36	36.08	36.11	11	11	17	95.9	91.1	96.5	96.9	..	..	96.9
100	24.73	22.17	24.77	25.39	24.98	25.20	25.17	15	45	17	15	13	09	17	94.7	78.4	95.5	96.5	94.0	93.6	96.5
125	..	20.11	..	..	..	..	..	..	53	..	..	..	..	..	..	65.4	..	..	..	..	..
150	22.90	17.21	23.51	23.92	24.47	24.78	24.25	36.42	29	36.35	36.58	36.40	36.33	36.60	82.4	54.6	94.8	..	78.7	86.0	82.5
200	19.36	14.36	20.76	20.96	20.99	21.88	21.98	44	35.82	56	69	69	69	69	60.2	52.6	65.6	68.7	68.7	70.6	71.1
300	14.32	10.65	16.01	16.42	16.91	16.9	16.73	35.86	28	08	31	26	31	26	47.3	45.6	51.7	67.3	64.4	65.9	67.2
400	11.02	8.67	12.19	13.36	14.00	15.32	13.39	34	01	35.52	35.70	35.75	35.99	35.70	45.3	41.8	48.3	53.1	55.4	57.9	50.1
500	8.75	7.76	10.32	10.84	11.05	12.84	10.89	05	34.90	26	28	32	59	30	42.0	43.9	45.8	46.5	46.6	49.2	45.6
600	7.26	..	8.67	9.08	9.18	10.25	8.76	34.88	..	03	07	07	23	03	42.5	..	43.0	43.7	40.7	43.9	43.7
700	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
800	5.70	..	6.30	6.80	6.33	6.92	6.18	34.87	..	34.81	34.85	34.85	34.87	34.87	50.7	..	42.8	44.1	44.8	44.5	48.0
900	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1000	4.85	..	5.24	5.84	5.01	5.05	..	34.92	..	34.90	34.85	34.88	34.88	..	58.8	..	52.2	49.1	..	55.3	..
2100	..	..	4.69	4.93	4.42	4.35	..	..	..	96	92	96	96	..	..	..	60.8	58.3	63.5	64.0	..
1500	..	..	4.28	4.27	4.16	..	..	..	..	35.01	96	96	..	..	..	..	67.6	67.0	69.4	..	..

Table 24. **Area XIX. 2.**

Depth m	Temperature						Salinity						Oxygen					
	1232	1233	1234	1235	1236	1237	1232	1233	1234	1235	1236	1237	1232	1233	1234	1235	1236	1237
0	24.78	23.73	24.57	24.92	24.83	24.80	36.18	36.17	36.06	36.06	36.08	36.17	98.0	96.6	97.7	97.8	98.0	97.7
25	91	34	36	86	83	81	17	18	08	06	08	17	94.7	97.4	96.7	98.4	97.7	98.0
50	89	22.81	23.89	86	83	82	17	17	17	06	08	17	97.5	97.2	97.0	97.3	96.9	97.3
75	78	35	26	23.99	80	57	24	18	40	29	09	17	94.7	93.9	86.7	91.9	96.5	94.9
85	..	20.16	..	..	..	..	..	08	..	..	..	..	..	84.7	..	..	..	..
100	56	14.91	22.10	22.87	23.76	24.26	36.27	51	36.27	36.17	36.35	36.35	94.5	63.5	92.1	95.2	92.5	91.4
125	..	..	20.7	..	..	..	..	..	19	..	..	..	..	..	69.1	..	..	..
150	23.52	..	16.59	21.27	22.51	23.61	36.65	..	11	36.42	..	36.62	85.7	..	51.8	74.7	94.1	71.7
200	22.40	..	12.66	17.99	20.26	20.86	71	..	35.55	35	36.60	62	71.6	..	37.6	62.4	65.8	66.7
250	19.07	..	10.77	15.22	17.40	18.56	56	..	..	35.82	27	44	70.2	..	45.3	49.7	66.3	66.5
300	17.54	..	9.64	13.55	15.86	17.55	44	..	35.12	70	08	35	76.8	..	44.3	52.3	63.8	65.7
375	..	..	8.05	..	..	..	..	..	34.94	..	..	..	..	..	43.5	..	..	..
400	14.93	..	..	10.93	13.09	14.98	36.00	..	..	35.28	35.64	35.91	64.4	..	..	47.0	53.0	58.8
490	13.79	..	..	..	..	..	35.81	..	..	..	..	..	60.1	..	..	..	..	..
500	..	..	..	9.30	10.27	12.95	..	..	..	35.08	35.19	35.62	..	..	..	41.4	44.1	55.0
588	11.26	..	..	..	..	..	35.39	..	..	..	..	..	48.6	..	..	..	..	..
600	..	..	..	8.33	8.70	10.18	..	..	..	34.92	35.01	35.19	..	..	..	41.7	41.7	44.0
650	..	..	..	..	..	9.90	..	..	..	..	..	03	..	..	..	..	..	42.7
700	..	..	..	7.46	7.25	..	..	..	..	34.87	34.85	..	..	..	..	44.0	44.4	..
800	..	..	..	6.39	6.12	..	..	..	..	87	85	..	..	..	..	47.1	48.5	..

and at several places the water-layers lying adjacent to one another are greatly mixed together. For this reason mean values of the temperature and salinity found at the different depths are not calculated.

Consideration of the tables and curves shows that the water from 250—300 metres down to the bottom has the characteristic properties of the Caribbean Sea. For depths from ca. 100 down to 250—300 metres, on the other hand, only the TS curves for the stations 1224, 1228, 1229 and 1231 show agreement with the curves for the western part of the Caribbean Sea for the same depths. The Caribbean water at these depths must therefore keep close to Cuba on its way through the Florida Straits. For the more northerly stations 1225, 1226 and 1227, lying nearer the Florida Reef, the maximum salinity in the depth interval mentioned is considerably less than at the southern stations, which is due presumably to the mixing of the layer of maximum salinity with the upper and under layers during the movement through the Gulf of Mexico.

For all the stations north of the west point of Cuba the water in the uppermost 100 metres has been greatly mixed and the surface salinity is consequently considerably higher (ca. 36 $^0/_{00}$) than in the Caribbean Sea, whilst the layer forms a comparatively uniform mass of water. After further mixture this water-mass flows out through the Bemini Straits forming the A-water previously mentioned.

Of the stations 1232—1237 lying in the Florida Straits near Bemini stat. 1232 and 1237 are situated almost at the same place in the easternmost part of the Straits. All the stations lie almost at the same latitude and in the direction from west to east in the order 1233, 1234, 1235, 1236 and 1237 (see section VI, p. 11 and the annexe-chart Fig. 63). It will be seen from the Table 24 and Fig. 47, that an essential difference in the salinity between the eastern and western parts of the Straits occurs in the intermediate layer at a depth of 150—200 metres.

The different conditions as regards temperature, salinity and oxygen contents in the Yucatan Channel and the Area XIX have however already been dealt with (p. 14), especially with regard to the water-layers where the intermediate maximum and minimum salinities occur.

As to the hydrographical features in the Areas now considered it is worth remarking that they are of special interest for the understanding of the formation of the water-masses in the Gulf Stream — the A-water — and water-masses prominent in the Sargasso Sea, which will now be considered. In a special sense one can say, that the situation of the West Indian islands in that part of the Atlantic accounts for the formation of the mentioned water-masses by the mixing processes occurring at the islands.

Area XX embraces the Sargasso Sea and the Gulf Stream between this and the east coast of America. This Area practically includes the whole of the North American basin.

Within this Area we have the "Dana" stations 1238, 1239, 1241, 1242, 1243, 1319, 1322, 1333, 1335, 1338, 1339, 1340, 1342, 1343, 1344, 1346, 1352, 1356 and 1357. The data and their means are reproduced in the usual manner in Fig. 48 and Table 22 p. 80. The graphic representation Fig. 48 also includes TS diagrams for the stations 1347 and 1351 which lie in the Norfolk section near the boundary of the Area. The hydrographical conditions at these stations are closely related to those found in Area XX, but are specially distinguished by the isotherms and isohalines of the CS-water lying in less depths than at the other stations in Area XX (cf. section IX and section IX a). For this reason the stations mentioned are not included in the means given in Table 22.

Of the stations in Area XX the TS diagrams for 1239, 1241, 1322, 1342, 1347 and 1356 have previously been dealt with (see pp. 38 and 45).

Consideration of Fig. 48 shows at once, that the hydrographical conditions in depths from 200—300 down to the greatest depths where observations were made, are very uniform for this Area XX. On the other hand, the water in the uppermost 200 metres is somewhat dissimilar in the various parts of the Area, even when showing the same general features. As Table 22 shows, the average salinity at the surface is 36.53 $^0/_{00}$. The surface salinity is greatest in the south-eastern part of the Area (37.1 $^0/_{00}$), less

in the north-western part (ca. 36.3 ‰) and least in the south-western part where stat. 1243 shows 35.84‰ But the surface conditions at the last-mentioned station differ so much from the normal conditions in the Area XX, that it should perhaps preferably be excluded. The surface salinity in the remaining south-west part of the Area is about 36.65 ‰.

The cause of these differences may first of all be sought for in the mixture of CE-water and underlying CS-water brought along by the Antilles Current and in the A-water brought by the Florida Current, which is likewise to be considered as CE-water. The A-water is specially noticeable at the stations 1347 and 1351, where even at the surface an admixture of low salinity from the Newfoundland Area has taken place.

The inflow of the E-water into this Area has led at most of the stations to the appearance of an intermediate salinity maximum at about 150 metres, due to the mixing of the E- and CS-waters. With regard to the connection between this maximum salinity and the distribution of the C-water and of the Florida and Antilles Currents, reference may be made to the earlier treatment of these conditions (p. 14).

For all the stations it holds good, that from 200—300 metres down to ca. 900 metres we find CS-water, the TS curves for these depths following closely the line CS. In the south-eastern part of the Area the CS-water reaches right up to the surface, where almost unmixed C-water is found.

The oxygen minimum is found at a depth of 800—900 metres with the contents 55 %. An approximate calculation of the oxygen contents from the mixing conditions of C- and S-waters gives 56%.

We thus find, that the CS-water is specially dominant in the Sargasso Sea and that this region is to be considered as a reservoir for this water. One may assume, that the CS-water is formed mainly in the West Indian waters and from there carried into the Sargasso Sea. Here it participates in the anticyclonic water movement until it is removed partly by the mixing that takes place along the north side of the Sargasso Sea, partly by mixing with the underlying JB-water. The latter however is probably of subordinate importance owing to the comparatively great stability of the JB-water. It is possible, however, that the M-water in the eastern part of the Atlantic is of essential importance for the mixing up of the CS-water, since these combined will more readily blend with the deeper layers.

Special conditions for the mixing of the CS-water with other waters are found in the eastern part of the Atlantic, in the Area of the Cape Verde Islands, as already noted (p. 74).

Within Area XX we find everywhere in depths of 4,000 metres and more unmixed bottom-water which may be characterized on the whole as B-water, though the temperatures in the greatest depths are slightly lower than those of B-water. Similarly the hydrographical conditions for depths between 900 and 4000 metres are mainly the same for the whole Area, as Fig. 48 shows. Between ca. 2000 and 4000 metres we have JB-water, to which is added some M-water in the eastern part of the Area, and between 900 and 1,500—2,000 metres lies a mixture of CS- and JB-waters.

It is possible, however, as already noted in discussing the TS diagrams for the stations 1322, 1356, 1342, 1347, 1239 and 1241, to detect the differences between the separate stations which have arisen through the inflowing of the M-water in the eastern part of the Area and through the inflow of the B-water especially in the western part of the Area down to the boundary of the American basin formed by the row of West Indian Islands.

Area XXI lies to the west of the Straits of Gibraltar and contains the "Dana" stations 1106, 1107, 1108, 1109, 1110, 1111, 1112 and 1113, the stations P 3 and P 5 of the German "Planet" Expedition 1906—07 (W. Brennecke 1909) as also the stations Mö 2, Mö 3, Mö 4 and Mö 5 of the German "Mövе" Expedition 1911 (G. Schott u. B. Schulz 1914). See chart Fig. 63.

The material from the stations mentioned is given by the means in Table 25 and by TS curves in Fig. 49. In the latter the curves for the "Mövе" stations are represented by discontinuous lines, just as for the areas along the African coast already discussed. For the remaining stations the TS curves are represented by continuous lines.

Fig. 49 shows that the hydrographical conditions within the Area considered are somewhat irregular. The water-masses between 100 and 600 metres may be characterized as mainly CS-water, though the TS curves have a somewhat irregular course and also lie on the whole slightly lower than the line CS. For the uppermost 100 metres several of the TS curves have an approximately vertical course owing to the heating of the water, which has obtained uniform temperature and salinity through the winter cooling, as already described for the Areas VIII and IX.

At a depth of ca. 1,200 metres the TS curves show the salt water which flows out of the Mediterranean. The mixture formed by this water and the Atlantic water at a depth of ca. 1,200 metres shows for this Area somewhat higher salinities than those of the M-water, which is due simply to the fact, that the M-water has been defined from water at stations lying outside Area XXI (see p. 31) owing to the greater uniformity of the mixture at some distance from the Straits of Gibraltar. Approximately however the water at a depth of ca. 1,200 metres down to the bottom may be regarded as MB-water. From 600 down to 1,200 metres we have a mixture of CS-water and the water mixed with Mediterranean water. The mixing conditions are however very different at the different stations.

According to the observations of the "Planet" Expedition the oxygen minimum (ca. 63 %) may be considered to lie at a depth of 600—700 metres.

Area XXII lies west and south-west of the Iberian Peninsula and contains the "Dana" stations 1104, 1105, 1381, 1383, 1384 and 1385, the station P 2 of the German "Planet" Expedition 1906—07 (W. Brennecke 1909), the station Mö 1 of the German "Möve" Expedition 1911 (G. Schott u. B. Schulz 1914) and the stations HN 21 and HN 32 from the report published by Helland-Hansen and Fridtjof Nansen on „The Eastern North Atlantic" (Helland-Hansen and Nansen 1926). The position of the stations is shown on the chart Fig. 63.

The material for the station is reproduced in Table 25 p. 87 and Fig. 50. The TS diagram for stat. 1383 has already been discussed p. 24.

Like the adjacent areas VIII and IX to the north and west the Area XXII belongs to the portion of the North-East Atlantic investigated by Helland-Hansen and Fridtjof Nansen and reference may be made to their report for the current conditions. A chart of the currents in 100 metres has already been given from this report (p. 67).

It will be seen from the diagram Fig. 50, that the water between 100 and ca. 500 may be regarded in the main as CS-water, though the TS curves lie a little lower than the line CS, which applies generally to this part of the Atlantic, possibly owing to the fact that JC-water with slightly different character is mixed with the CS-water. That the water in this area is not wholly CS-water coming unmixed from the Sargasso Sea can be seen especially from the relatively large oxygen contents in the depths considered. At 400 metres, where the salinity on an average is 35.54 ‰, for example the oxygen, has the mean 84.3 %. This feature has already been discussed on comparing stat. 1383 with the stations farther to the west (p. 37).

Just as in the Area VIII the CS-water here shows comparatively small differences in salinity and just as in the adjacent areas the TS curves for the uppermost 100 metres have for several of the stations a vertical course on the whole, owing to the exchange of heat with the atmosphere.

In accordance with the definition of M-water, this occurs essentially unmixed at a depth of ca. 1000 metres. It may be remarked that a specially high salinity, 36.10 ‰, was noted at 1,100 metres at stat. 1385, which is included in the calculation of the salinity of the M-water (see p. 31). This corresponds with the fact, that the water flowing out from the Mediterranean mainly follows the continental shelf. Lower salinities however were found at the near-lying station 1104, so that the conditions may be somewhat variable.

In depths greater than 1,000 metres we find MB-water, which in depths greater than 2,000 metres is essentially B-water. At 2,000 metres we find the high oxygen contents 84 %.

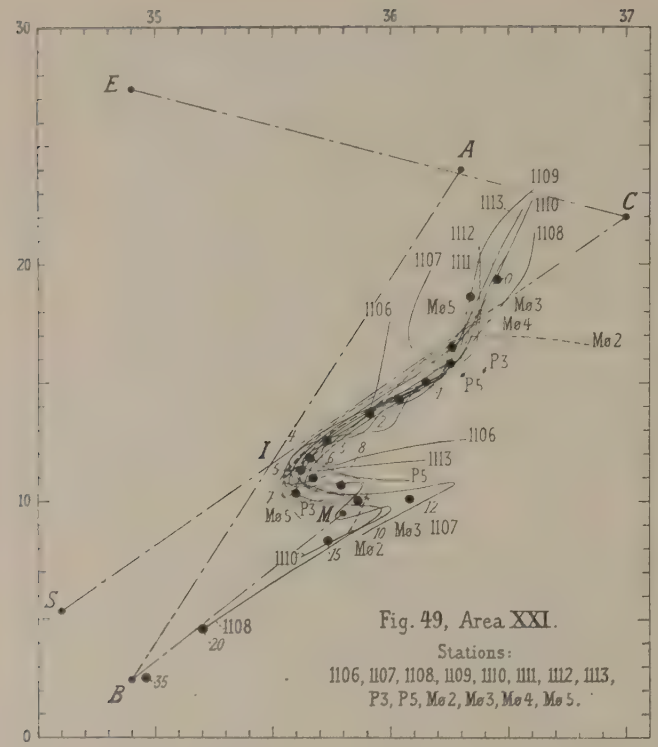

Fig. 49, Area XXI.

Stations:
1106, 1107, 1108, 1109, 1110, 1111, 1112, 1113,
P3, P5, Mø2, Mø3, Mø4, Mø5.

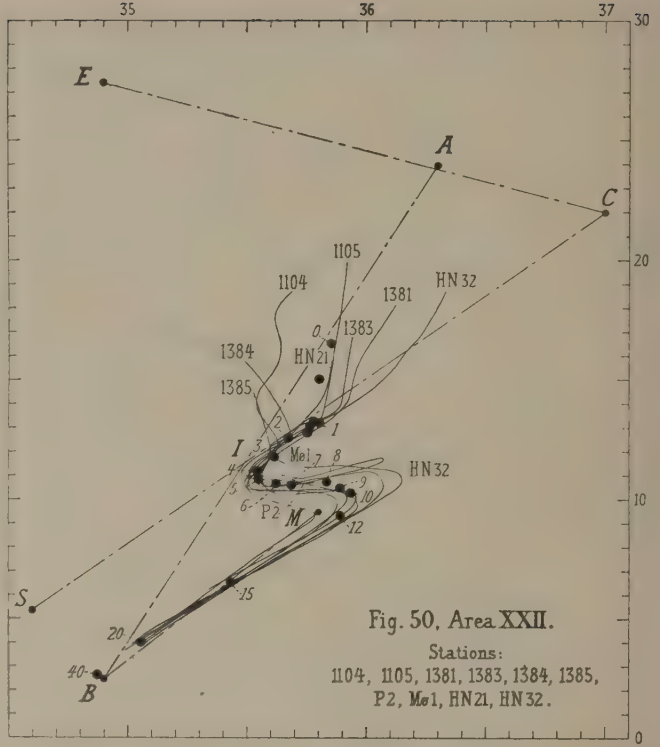

Fig. 50, Area XXII.

Stations:
1104, 1105, 1381, 1383, 1384, 1385,
P2, Mø1, HN21, HN32.

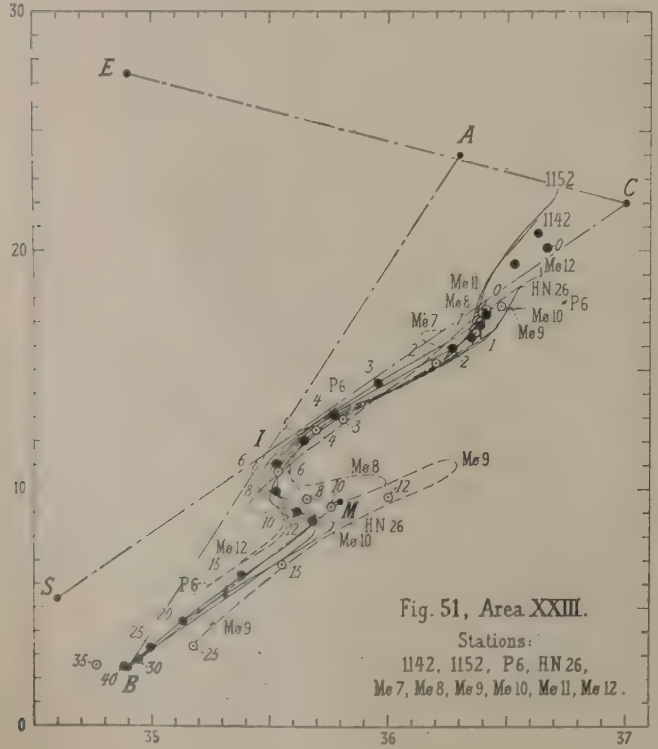

Fig. 51, Area XXIII.

Stations:
1142, 1152, P6, HN26,
Mø7, Mø8, Mø9, Mø10, Mø11, Mø12.

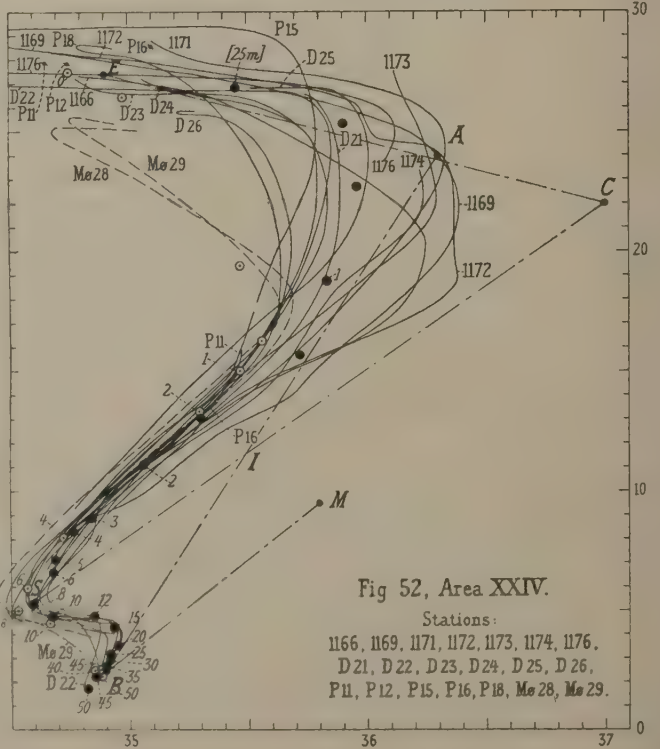

Fig 52, Area XXIV.

Stations:
1166, 1169, 1171, 1172, 1173, 1174, 1176,
D21, D22, D23, D24, D25, D26,
P11, P12, P15, P16, P18, Mø28, Mø29.

Between 600 and 1,000 metres we have a mixture of CS-water and M-water. The oxygen minimum (70.3 %) lies at 1,000 metres in the M-water.

Area XXIII lies south of the Area XXII and includes Madeira and the Canary Isles. It contains the "Dana" stations 1142 and 1152, the station P 6 from the German "Planet" Expedition 1906—07 (W. Brennecke 1909), the stations Mö 7, Mö 8, Mö 9, Mö 10, Mö 11, and Mö 12 from the German "Möve"

Table 25.

Depth m	Area XXI			Area XXII			Area XXIII[1])					Area XXIV[1])				
							I	II	I	II	I	I	II	I	II	I
	Temp. Mean	Salin. Mean	Oxyg. Mean	Temp. Mean	Salin. Mean	Oxyg. Mean	Temp. Mean	Temp. Mean	Salin. Mean	Salin. Mean	Oxyg. Mean	Temp. Mean	Temp. Mean	Salin. Mean	Salin. Mean	Oxyg. Mean
0.....	19.31	36.45	99	16.51	35.85	105.1	20.08	17.58	36.67	36.48	97.0	27.47	27.43	..	34.75	98.3
25.....	18.64	34	..	16.57	85	105.0	20.69	17.52	63	41	97.0	26.79	26.39	35.45	98	97.7
50.....	16.46	26	..	15.05	80	110.6	19.38	17.41	53	40	98.0	25.30	19.33	90	35.47	92.5
75.....	15.75	25	..	13.26	78	99.5	17.31	17.02	41	39	94.1	22.69	16.26	96	56	75.8
100.....	15.05	15	..	13.05	76	98.4	16.85	16.49	39	37	80.4	18.71	14.95	83	47	61.3
125.....	..	..	..	13.20	80	97.9	..	..	..	..	..	15.66	..	72	..	54.2
150.....	14.24	36.04	..	12.80	75	97.8	16.37	..	36.35	36.29	87.2	13.04	..	30	..	48.5
200.....	13.68	35.91	..	12.57	67	92.6	15.88	15.26	27	20	82.7	11.04	13.30	06	35.30	45.1
300.....	12.52	73	..	11.78	61	89.2	14.39	12.96	35.96	35.81	80.2	8.86	..	34.84	..	41.1
400.....	11.79	66	80	11.14	54	84.3	13.08	12.45	77	70	76.1	8.26	8.06	76	34.72	37.9
500.....	11.30	62	..	10.86	55	80.6	12.03	..	65	..	67.2	7.07	..	69	..	37.3
600.....	10.93	67	63	10.65	62	75.4	11.12	10.75	53	35.54	68.4	6.56	5.86	68	34.57	38.5
700.....	10.32	60	..	10.58	68	73.6	10.30	..	51	..	..	..	..	..	..	..
800.....	10.66	79	65	10.71	83	70.4	9.92	9.60	53	35.66	62.2	5.24	4.92	34.59	34.53	39.7
900.....	..	..	..	10.47	89	70.8	..	..	..	..	..	..	..	..	..	..
1000.....	10.01	35.86	66	10.31	93	70.3	9.04	9.27	35.61	35.76	61.2	4.73	4.42	34.67	34.66	46.2
1200.....	10.08	36.08	..	9.32	89	70.9	8.64	9.66	68	36.00	62.9	4.70	..	85	..	53.2
1500.....	8.32	35.73	..	6.51	43	80.6	6.40	6.81	38	35.55	69.2	4.25	..	93	..	65.4
2000.....	4.61	20	..	4.01	05	83.9	4.46	..	13	..	72.0	3.52	..	95	..	66.6
2500.....	..	..	..	..	..	..	3.28	3.35	34.99	35.17	67.3	3.10	..	92	..	65.2
3000.....	..	..	..	..	..	..	2.86	2.63	94	..	64.4	2.88	..	92	..	57.6
3500.....	2.48	34.96	..	..	..	..	..	2.56	..	34.76	..	2.60	..	90	..	63.2
4000.....	..	..	..	2.61	34.87	..	2.50	..	34.88	..	45.2	2.41	..	88	..	62.3
4500.....	..	..	..	..	..	..	..	..	..	..	..	2.17	2.50	85	34.88	47.0
5000.....	..	..	..	..	..	..	..	..	34.88	..	..	1.66	2.20	82	34.88	68.0

[1]) The area divided in part I and II, part II contains the stations near the coast of Africa and parts I the remaining stations.

Expedition 1911 (G. Schott u. B. Schulz 1914) and the station HN 26 from B. Helland-Hansen and Fridtjof Nansen's report on "The Eastern North Atlantic" (1926). The position of the stations is shown in the chart Fig. 63.

The material from the stations mentioned is used in the usual manner for table 25 above and Fig. 51 p. 86 but a distinction is drawn between the "Möve" stations and the others, the means for the two groups of stations being given separately. Further the TS curves for the "Möve" stations are given as discontinous lines in Fig. 51.

Of the stations in Area XXIII the stat. 1142 has already been discussed (p. 39) in dealing with the TS diagrams for special stations.

In several respects the TS diagrams for this and the preceding Area show great similarity. The chief difference is found in the CS-water occurring in depths between 100 and 600 metres, which has much more variable salinity and temperature in Area XXIII than in Area XXII. In XXIII also there is probably an infusion of JC-water in the CS-water of the spot, but it should be remarked, that the oxygen

contents of the mixture occurring in Area XXIII are considerably lower than for Area XXII. Apart from a slight admixture of JC-water, this may also be due to the stagnation of the water already noticeable here and very marked in the more southerly areas XI and XII.

From 1,000—1,200 metres down to greater depths we find MB-water, with its highest salinity considerably lower than those in Area XXII, except at stat. Mō 9 which lies near Area XXI. Between 600 and 1,000—1,200 metres we find a mixture of CS- and M-water and in the deepest part of this mixture, which consists essentially of M-water, there is an oxygen minimum of ca. 61 %. As this amount is essentially lower than that of the M-water, it points to a slow movement of the water at this depth.

The MB-water, mainly B-water, present in the greatest depths, has very low oxygen contents corresponding to the already mentioned stagnation of the water in great depths in this Area.

Even though some difference is present in the TS curves for the "Mōve" stations and those for the other stations in Fig. 51, this difference, which concerns the salinity at the same depth near the African coast and farther out, does not appear in the course of the curves. This is due to the fact that near the African coast and farther out we have the same kind of water, a condition previously mentioned under Area XI. On the other hand, the difference in water of the same level is shown clearly in the averages given in Table 25.

Area XXIV is a belt extending across from Africa to America between the equator and ca. 10° N. Lat. It contains the "Dana" stations 1166, 1169, 1171, 1172, 1173, 1174 and 1176, the stations D 21, D 22, D 23, D 24, D 25 and D 26 of the German Antarctic Expedition 1911—12 (W. Brennecke 1921), the stations P 11, P 12, P 15, P 16 and P 18 of the German "Planet" Expedition 1906—07 (W. Brennecke 1909) and the stations Mō 28 and Mō 29 of the German "Mōve" Expedition 1911 (G. Schott u. B. Schulz 1914). The position of the stations is shown in the chart Fig. 63.

The material from the stations mentioned is used for Table 25 p. 87 and Fig. 52 in the usual manner. Two groups of stations are however distinguished, the one containing the "Planet" and "Mōve" stations all lying near the African coast, the other the remaining stations. In Fig. 52 the TS curves for the two "Mōve" stations are given by discontinous lines. The mean values of the temperature and salinity for the different depths are plotted for both groups of stations.

Of the stations mentioned stat. 1166 and 1173 have already been discussed (p. 42) in dealing with the special TS diagrams.

Consideration of the TS diagrams for the stations in this area shows, that the hydrographical conditions in the uppermost layers down to a depth of ca. 200 metres vary greatly, partly with the depth, partly from station to station.

Table 25 shows that a salinity maximum occurs at a depth of 50—100 metres. most marked in the western part of the Area. This salt water is due to the C-water coming from the north, but this has become greatly mixed during its passage towards the south-west. From the surface down to the depth in which the maximum occurs, the mixing is with the E-water carried by the Equatorial Current.

Below the water-layer with maximum salinity the salinity greatly decreases and reaches down to 35 ‰ already at 200 metres and then obtains the minimum value 34.5—34.6 ‰ at ca. 800 metres. According to the definition of the S-water, this minimum is almost equal to the salinity of the S-water.

For depths between 200 and 800 metres the TS curves have the same direction as the CS line but lie higher than this and we have here, as mentioned earlier (p. 42), a mixture formed south of the equator in analogous manner to the CS-water north of the equator. The TS diagram for this mixture is given in Fig. 19 p. 42. Comparing that diagram with the TS diagram for the present Area we see that the agreement is best in the eastern part of the Area, especially near the African coast. The mixture has therefore made its way in chiefly in the eastern part of the Area XXIV and has then spread north-west

in over Area XIII, as already described. During the further movement of the water it may either be taken up with the CS-water entering the Caribbean Sea or transported southwards along the coast of South America.

The oxygen contents in this mixture, as can be seen Table 25, are but small with lower minimum value than that of the S-water.

From 1,500—2,000 metres down to greater depths we find JB-water, which consists mainly of B-water. Here the Antarctic bottom water makes its influence felt as previously mentioned (p. 22). The oxygen contents, as shown by the Table 25, are almost the same as for the B-water in Area XIII and considerably lower than for the B-water in the northern and western areas.

Between 800 and 1,500—2,000 metres lies SB-water with some admixture of J-water.

With regard to the special conditions at the African coast, Table 25 shows, that the temperature and salinity occurring there are essentially the same as in the previously mentioned areas which touch the coast. In agreement with the fact that water occurs near the African coast, which originally came from deeper layers, the Planet observations also show that smaller quantities of oxygen are found at the same depth near the surface than at the stations lying more to the west.

In the western part of the Area we notice the low surface salinities at station 1174 and 1176 which are undoubtedly due to the influence of the Amazon River.

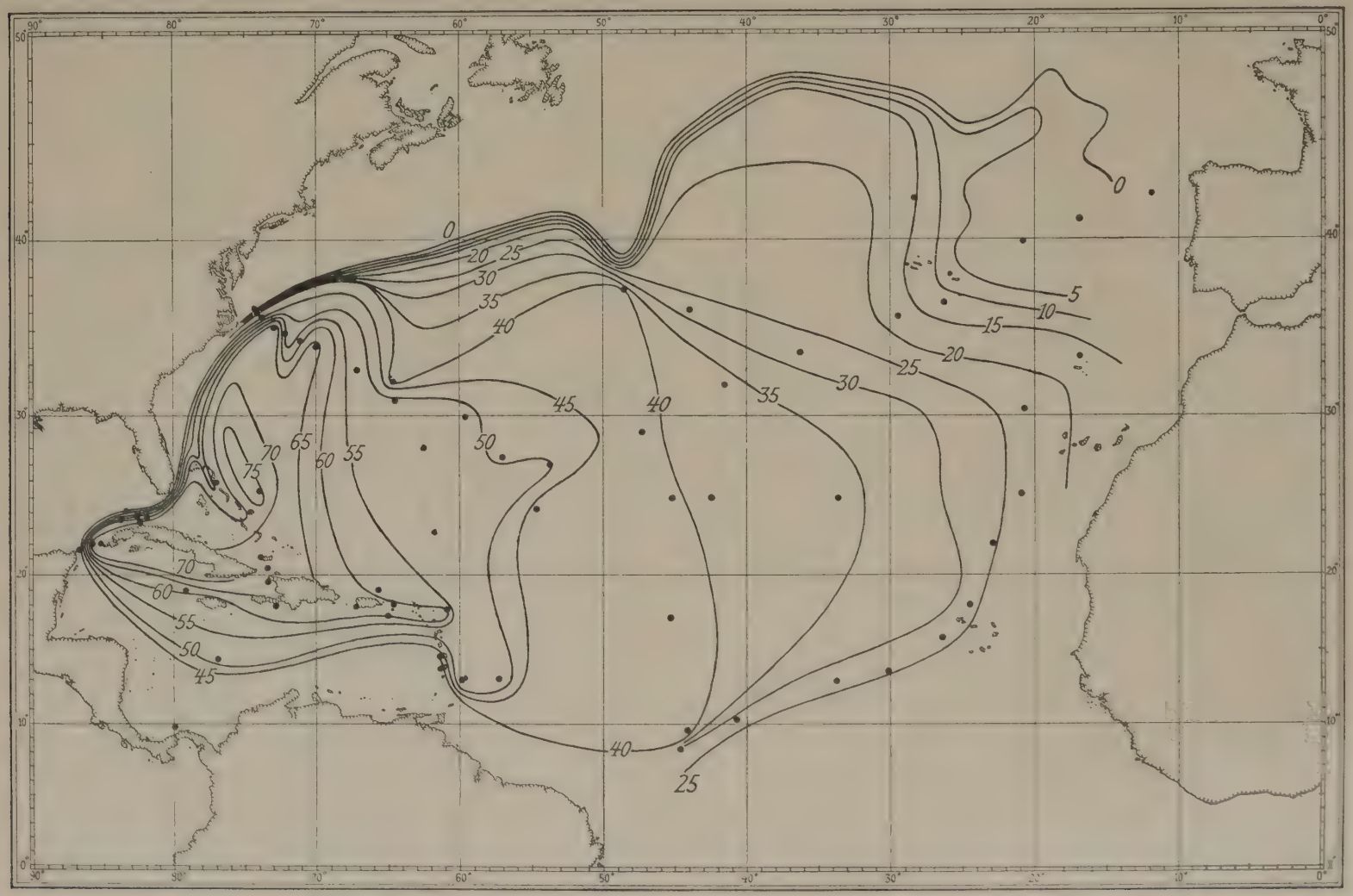

Fig. 53. Topographical chart at the surface with curves for every 5 cm. Depth of reference 1000 metres.

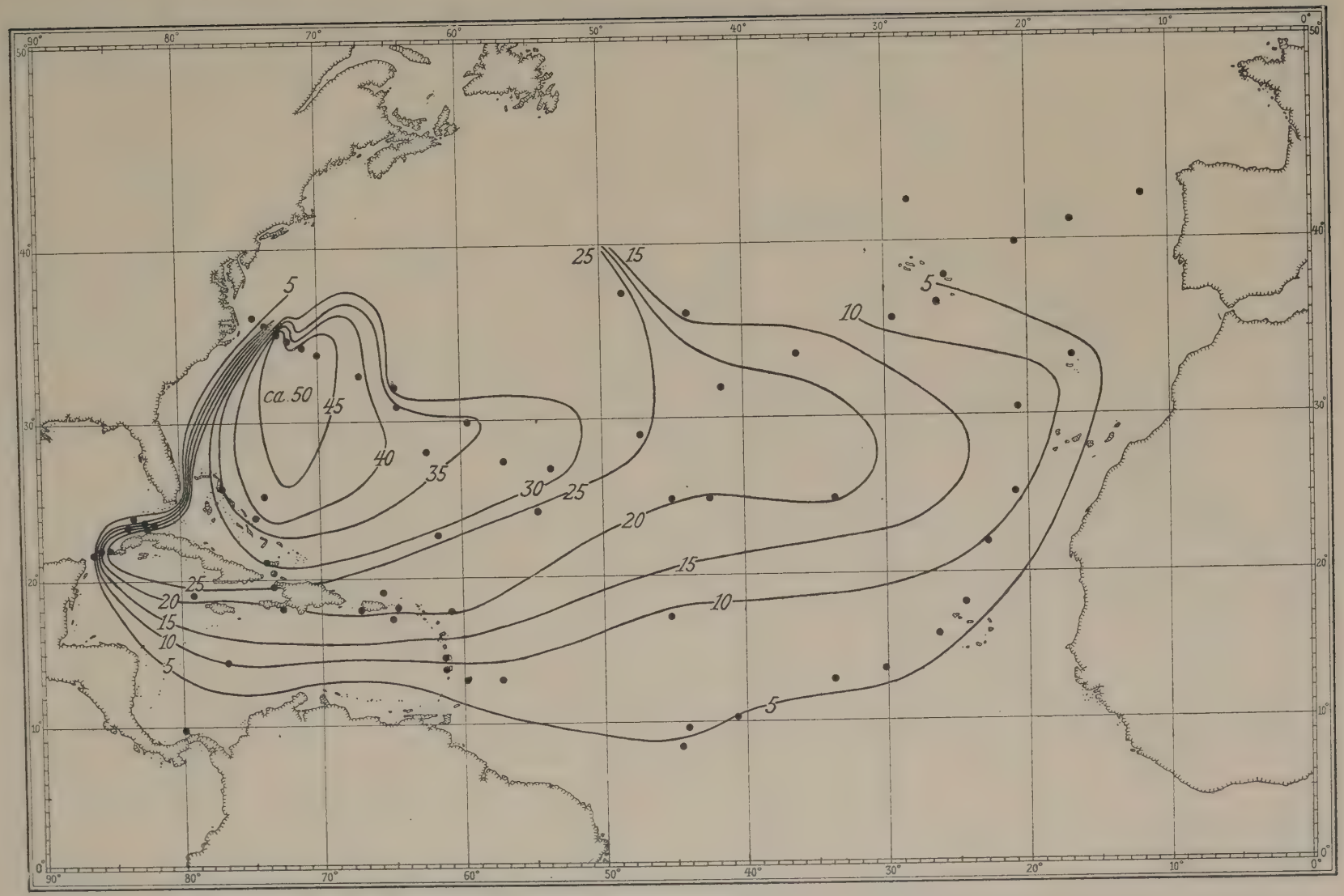

Fig. 54. Topographical chart at 200 m. with curves for every 5 cm. Depth of reference 1000 metres.

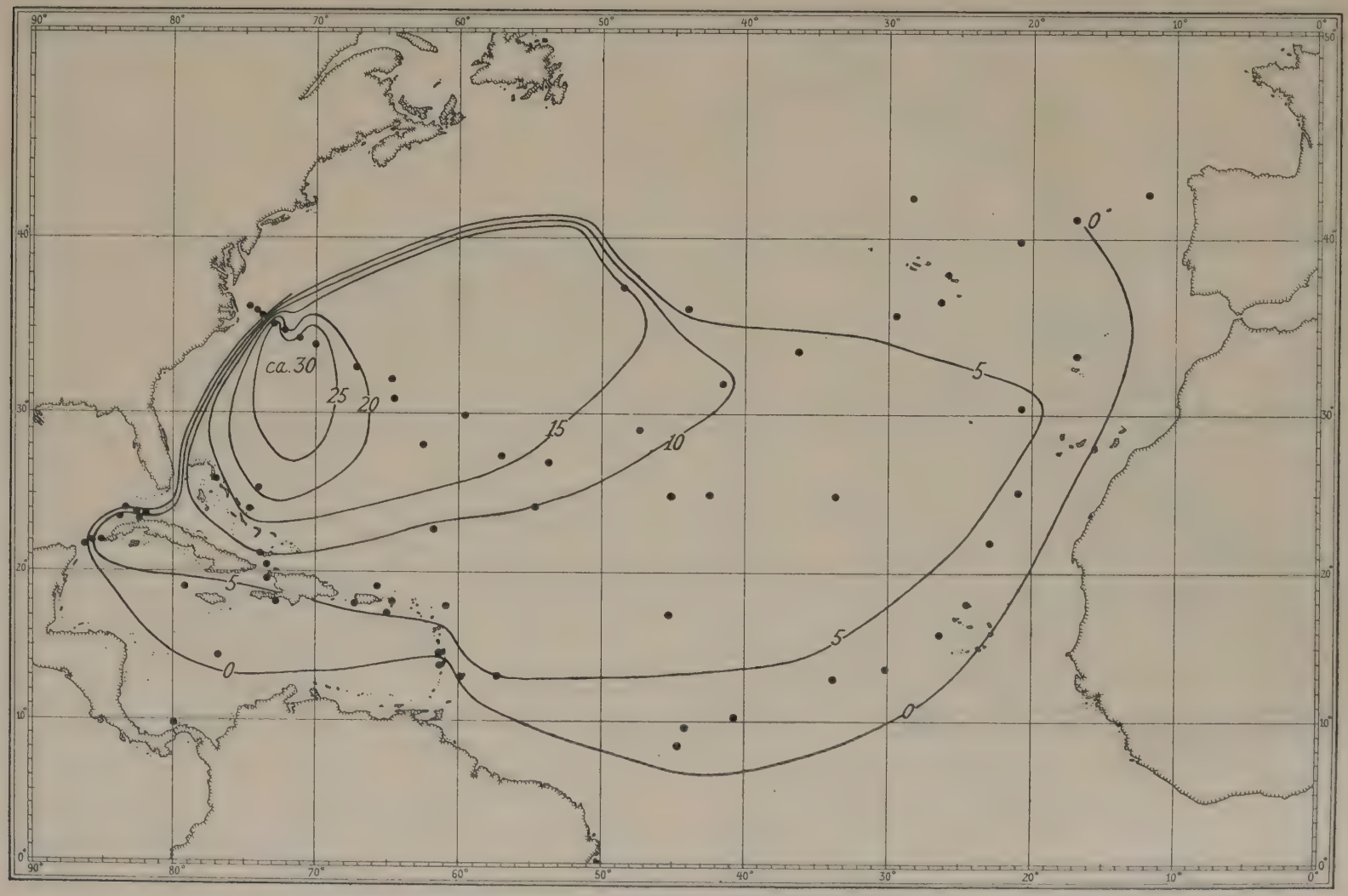

Fig. 55. Topographical chart at 500 m. with curves for every 5 cm. Depth of reference 1000 metres.

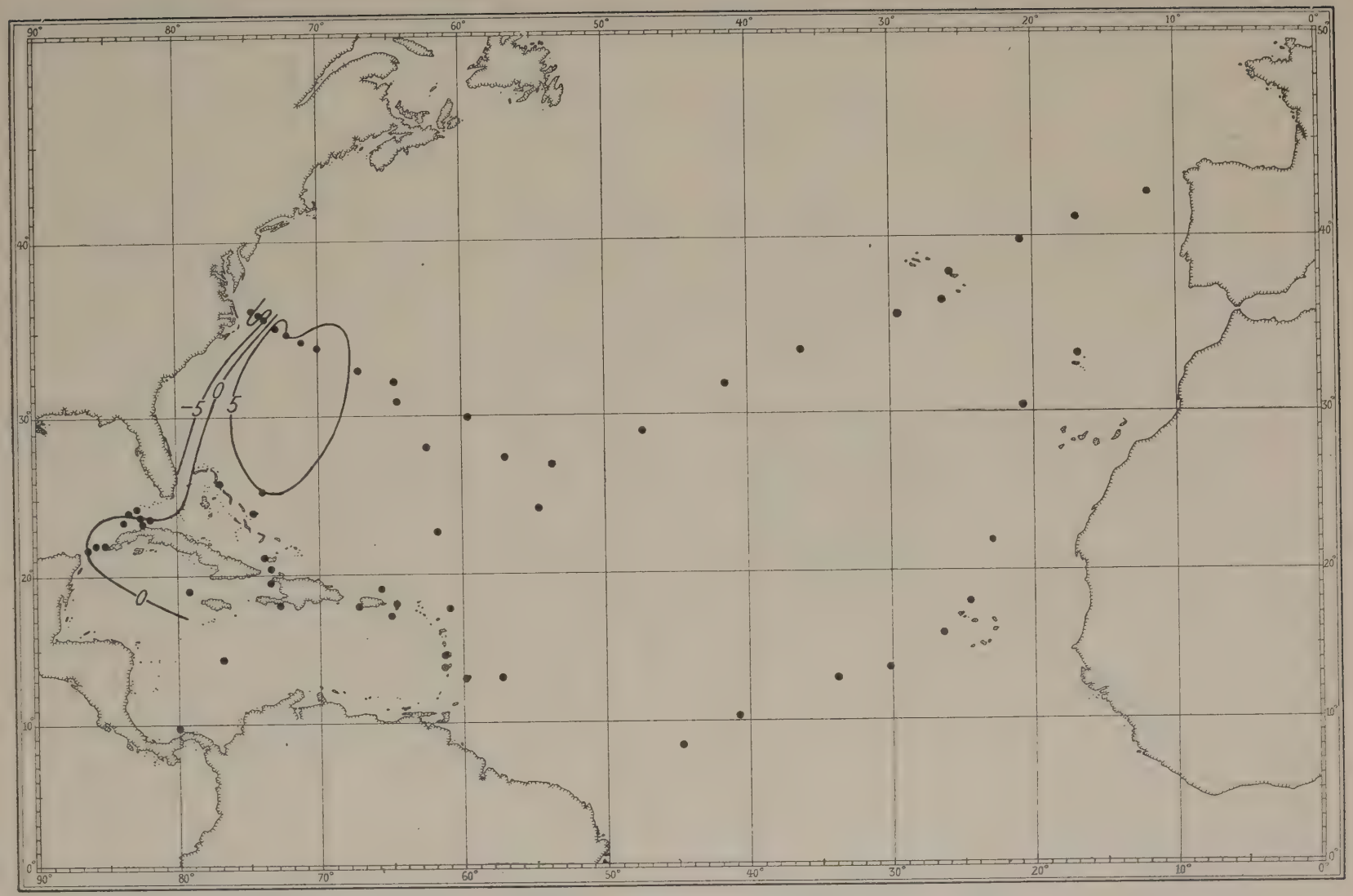

Fig. 56. Topographical chart at 800 m. with curves for every 5 cm. Depth of reference 1000 metres.

5. GENERAL REMARKS

In the preceding pages an endeavour has been made to give an analysis of the water-masses which occur in the North Atlantic between the equator and ca. 60° N. Lat., chiefly on the basis of the material collected by the "Dana" Expedition (see p. 3).

In Chapter 2 an account has been given of the temperature and salinity conditions within the region considered, using for this purpose the sections represented in the figures 2—11 and 13—14; the position of the sections is noted on the Chart, Fig. 1.

Chapter 3 discusses the characteristic water-masses occurring and their mixtures with the aid of TS diagrams (p. 23). Along with these diagrams a graphic representation is given of the stability conditions in the different water-layers.

As mentioned on p. 28 and following pages, (see Fig. 16) six different main types of water-masses have been distinguished in this investigation, namely:

1. A-water ($T = 24°$, $S = 36.3\,‰$, O_2 sat. $= 96\,\%$) which in 0—100 metres is carried by the Florida Current and the Antilles Current northwards to the Newfoundland region.

2. B-water (T in situ $= 2.5°$, $S = 34.90\,‰$) which occurs at great depths (> 3000 m) in the north Atlantic. It comes mainly from the Greenland regions, where it has sunk down from the surface and then moved in the main southwards in the western part of the North Atlantic.

3. C-water ($T = 22°$, $S = 37.0\,‰$, O_2 sat. $= 98\,\%$) which occurs at a depth of ca. 100 metres in a belt from the Canary Isles to Porto Rico and comes chiefly from the central warm and salt surface-water at ca. 25° N. Lat.

4. S-water ($T = 5.4°$, $S = 34.6\,‰$, O_2 sat. $= 40\,\%$) which occurs in the intermediate layers at a depth of 700 to 800 metres between the equator and ca. 10° N. Lat. This water has its origin in the intermediate layer coming from the south which has sunk down from the surface at ca. 50°—60° S. Lat.

5. M-water ($T = 9.5°$, $S = 35.8\,‰$, O_2 sat. $= 68\,\%$) occurring as an intermediate layer at a depth of ca. 1000 metres in the region between the Azores and the Straits of Gibraltar. This water has arisen through the mixing of Mediterranean water with the Atlantic water present in the region mentioned.

6. E-water ($T = 27.4°$, $S = 34.9\,‰$, O_2 sat. $= 98\,\%$) occurring as surface water in the neighbourhood of the equator (Equatorial Current).

Mixing of these water-masses with one another produces the different kinds of water-mixtures according to the geographical conditions. The temperature and salinity of the products vary greatly as a rule with the mixing conditions, but a good picture of them is often obtained by the use of TS diagrams (see p. 23). Mixtures may occur however under special conditions where the temperature and salinity are almost constant. Such a mixture is the J-water described in p. 34 with the temperature 11.5° and salinity $35.5\,‰$. This water may be imagined to have arisen in three ways, namely, (1) as a mixture of A- and B-water; (2) as a mixture of C- and S-water; (3) as a surface mixture at 40°—50° N. Lat.

Figs. 17—21 give TS diagrams for selected stations to show the kinds of mixed water occurring there. The stations represented in the figures are marked on the Chart, fig. 63.

Chapter 4 gives an analysis of the water-masses occurring in the whole region according to the method explained in Chap. 3. As shown on the Chart fig. 63, the region is divided into 24 smaller areas and for all the stations in each area TS curves have been drawn in the diagrams (see Figs. 25—52). The areas have been chosen according to the hydrographical conditions, where these were to some extent uniform within each area. From p. 49 to p. 89 these areas have been described separately.

In addition to the observations made on the "Dana" Expedition, which have been discussed in the chapters mentioned, materials from other expeditions have been made use of and likewise the results

which have been published from various sides during the preparation of this work. Yet it is only a comparatively small part of the copious literature on the hydrography of the Atlantic, which could be directly considered in the present investigation. This must be regarded first of all as a discussion of the material of the „Dana". A copious summary of the available literature and of the results obtained by various expeditions is given by G. Schott in his recently published handbook: Geographie des Atlantischen Ozeans 2te Aufl. (1926). The latter also gives current charts and average charts for the temperature and salinity at the surface, 400 metres and 1000 metres depth.

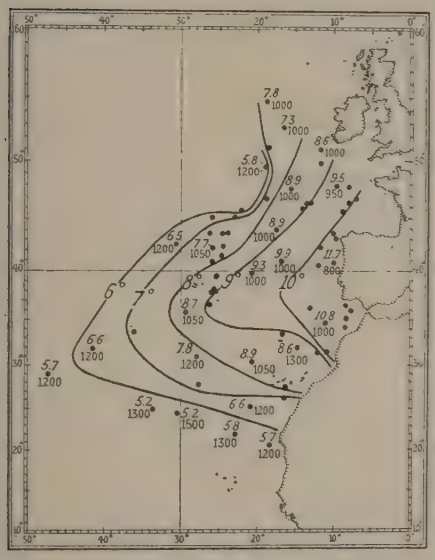

Fig. 57. Temperature.

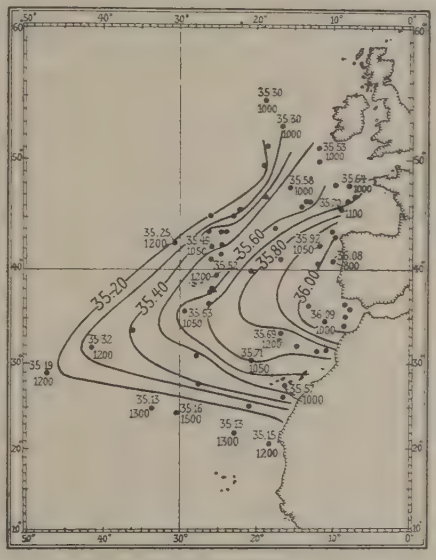

Fig. 58. Salinity.

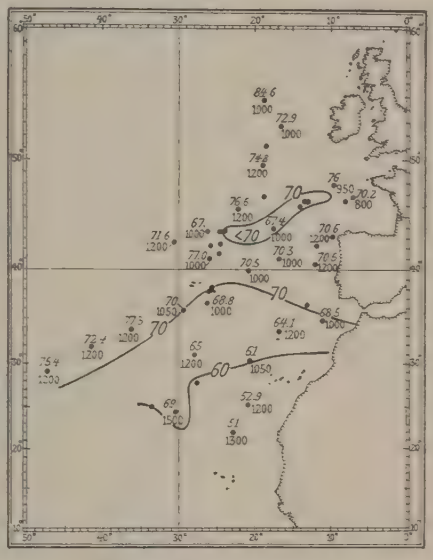

Fig. 59. Oxygen.

Figs. 57, 58 and 59 indicate the distribution and mixing of the Mediterranean water with the surrounding Atlantic water.

The charts represented in Figs. 53—62 have been drawn up to assist in the comprehension of some of the hydrographical conditions displayed, with a single exception, in the material directly used in the preceding pages.

Of these Figs. 53—56 are topographical charts for the surface, 200 m., 500 m. and 800 m., the 1000 metres depth being chosen as depth of reference. The curves indicate the different levels of the isobar surfaces with heights in cm. above the Zero point chosen in the surface at the Iberian peninsula. In the northern part of the region the isobar chart constructed by W. Ekman and Helland-Hansen (W. Ekman 1923) has been used for the isobars of the surface. The method employed in the construction of the charts has been that indicated by V. Bjerknes (1910), starting with a pressure equilibrium at a depth of 1000 metres. That this assumption is at least approximately correct, is confirmed by the slow movement of the water in depths about 1000 metres, as shown in the preceding pages and earlier demonstrated by Merz and G. Wüst (1922 and 1923).

Assuming now that the level curves drawn on the charts Figs. 53—56 indicate the direction of the currents produced by differences of pressure in the sea and that their closeness likewise indicates the strength of the current, we see that the level curves in the main give the same picture of the water movements as has been revealed on the basis of the distribution of the temperature and salinity. This has already been noticed occasionally in the foregoing. We must also take the wind into account as contributory cause of the actually occurring currents in the uppermost layers. A comparison with a chart of the pre-

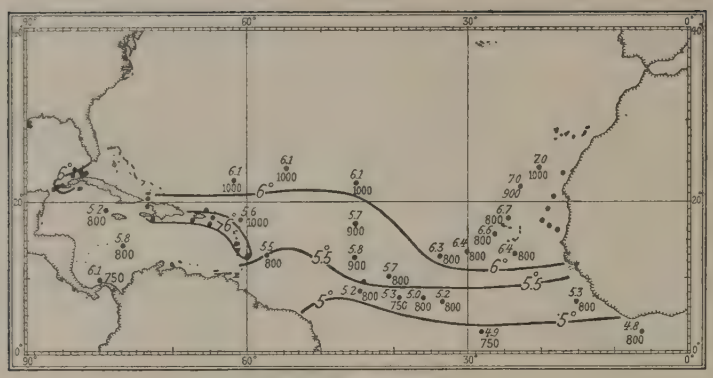

Fig. 60. Temperature.

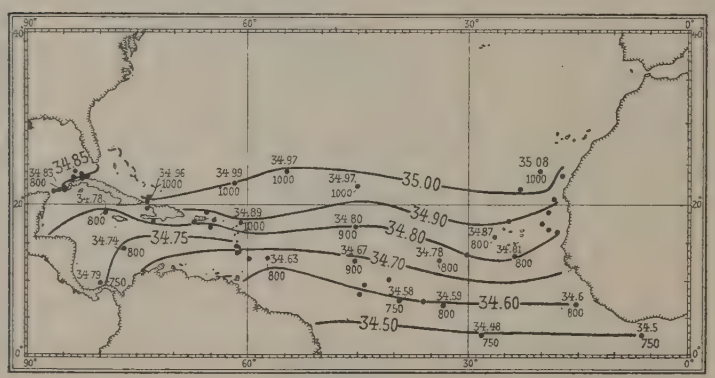

Fig. 61. Salinity.

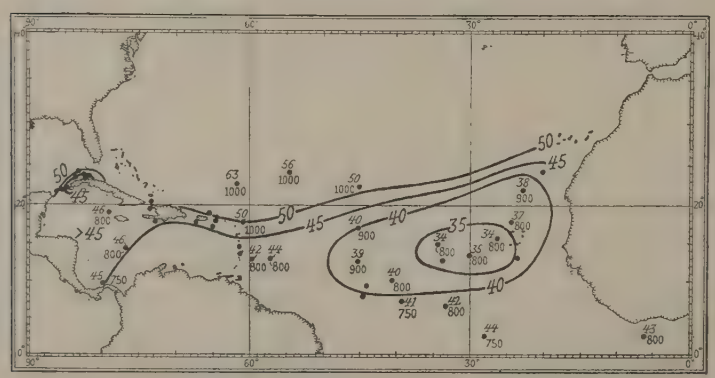

Fig. 62. Oxygen.

Figs. 60, 61 and 62 indicate the distribution and mixing of the intermediate water at 800—1000 m. with the surrounding waters.

vailing winds over the region dealt with, shows that the wind really strengthens the currents produced by the differences of pressure.

It should be mentioned that the charts discussed here were drawn before HELLAND-HANSEN and FRIDTJOF NANSEN's work on the Northeastern Atlantic was published. For the latter region reference may be made to the detailled dynamic charts given in the work mentioned.

The Figs. 57, 58 and 59 give charts of the distribution and mixing up of the Mediterranean water, the isotherms, isohalines and lines for the same oxygen contents being represented. At the stations marked on all three charts are noted the depth of maximum salinity and likewise the temperature, salinity and oxygen contents for the depth indicated. The curves have been drawn on the basis of these values.

We see from the charts how the Mediterranean water spreads out over the adjacent areas and prominently towards the north. It gradually becomes more and more mixed with the surrounding Atlantic water and sinks down to greater depths.

The Figs. 60, 61 and 62 indicate the distribution and mixing up of the S-water between the equator and ca. 20 N. Lat. by means of isotherms, isohalines and lines for the same oxygen contents, in the same manner as for the Mediterranean water. Alongside the stations noted are given the depth at which the salinity has its minimum as also the temperature, salinity and the oxygen contents at this depth. The curves have been drawn on the basis of these values.

We see how the mixing of the S-water with the surrounding water during its advance northwards has the effect of gradually raising the temperature, salinity and oxygen contents of the water with the minimum salinity. The chart of the oxygen contents shows the small amount of oxygen, below 34 $^0/_0$, in the region near the Cape Verde Islands where, as mentioned earlier, there may be considered to be a very slow movement of the water at depths of about 800 metres.

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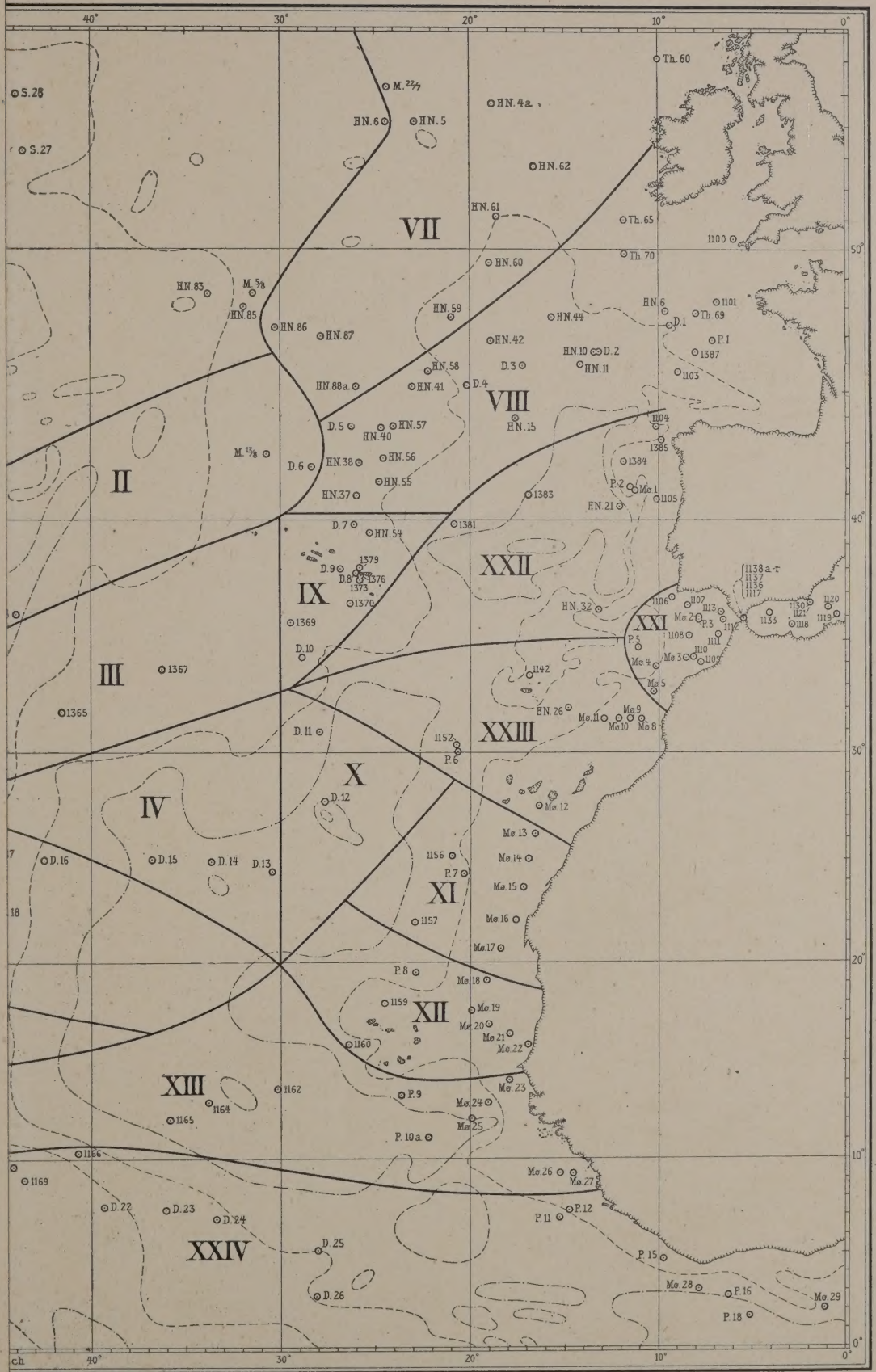

areas mentioned in the paper.